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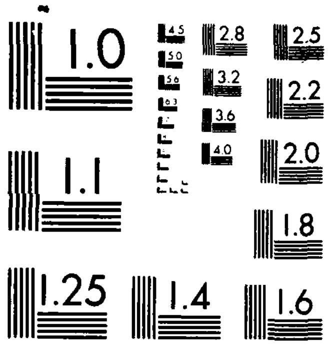

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A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE

by

JOHN W. STONE, MAJ, USAF
B.B.A., Ohio University, 1971

Fort Leavenworth, Kansas
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by Major John W. Stone, USAF, 120 pages.

The Airlift Master Plan was developed as a guide for achieving long-term military airlift objectives. The cornerstone of the plan is the development and acquisition of the C-17. Although the C-17's "direct-delivery" concept is new, the quest for expanded aircraft versatility has been continually pursued in previous airlift aircraft development programs. Thus the C-17 is not the first aircraft that has attempted to combine the traditionally separate roles of intertheater and intratheater airlift.

The most recent attempt at developing an aircraft capable of meeting both strategic and tactical requirements resulted in the C-5A. The C-5A failed to achieve the operational versatility predicted by its proponents and that failure has given rise to serious questions in regards to the C-17's probability of success in realizing its expanded airlift goals.

A comparison of the C-5A and C-17 programs revealed the differences in concept formulation, design and acquisition strategy which will allow the C-17 to achieve its operational goals. The study further concludes that the "direct-delivery" concept is a valid airlift objective and current technology permits the development of an aircraft with the performance capabilities necessary to fulfill that objective.

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The Airlift Master Plan was developed as a guide for achieving long-term military airlift objectives. The cornerstone of the plan is the development and acquisition of the C-17. Although the C-17's "direct-delivery" concept is new, the quest for expanded aircraft versatility has been continually pursued in previous airlift aircraft development programs. Thus the C-17 is not the first aircraft that has attempted to combine the traditionally separate roles of intertheater and intratheater airlift.

The most recent attempt at developing an aircraft capable of meeting both strategic and tactical requirements resulted in the C-5A. The C-5A failed to achieve the operational versatility predicted by its proponents and that failure has given rise to serious questions in regards to the C-17's probability of success in realizing its expanded airlift goals.

A comparison of the C-5A and C-17 programs revealed the differences in concept formulation, design and acquisition strategy which will allow the C-17 to achieve its operational goals. The study further concludes that the "direct-delivery" concept is a valid airlift objective and current technology permits the development of an aircraft with the performance capabilities necessary to fulfill that objective.

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CHAPTER 1

INTRODUCTION

24 January 1951

> "...It appears that three types of transport aircraft are required at the present time by the Air Force: a long range heavy lift aircraft capable of moving heavy equipment, another for handling airborne operations, and an assault type transport capable of operation into small marginal type airstrips. Although three types are essential at this time, our goal should be, insofar as possible, standardization of transport aircraft so they can effectively accomplish any type of air transport mission. Future transport aircraft design and development should point to greater versatility and the reduction of types."
>
> William H. Tunner
> Major General, USAF
> Commander, 315 Air Division[1]

Today, some thirty-four years after the above observation, the United States Air Force is still striving for the level of versatility in airlift aircraft that General Tunner envisioned. In fact, a very similar statement could be made regarding the three primary aircraft that make up the present airlift force. The continued utilization of three different aircraft types to accomplish the gamut of airlift requirements, however, does not mean that the general's goal has been ignored. Quite the contrary, each aircraft acquired since General Tunner's

petition for a reduction in aircraft types has attempted to achieve greater versatility than its predecessor.

In the same year as General Tunner's statement, the Tactical Air Command submitted specifications for a medium-sized cargo aircraft that was to evolve into probably the most versatile airlift aircraft built to date; the C-130 Hercules.[2] Originally designed as an assault transport, more than 35 versions of the C-130 presently exist encompassing a wide diversity of mission employment options.

The C-130 was the first American airplane to incorporate turboprop powerplants. This single technological advance gave the Hercules a tremendous advantage in power and lightness when compared to the reciprocating piston engine airlifters of its time.[3]

The aircraft design took advantage of other new concepts, such as lightweight metal alloys, to increase its capability. It was a less complex design than previous airlift aircraft, requiring only approximately 75,000 parts to manufacture. The use of new materials and manufacturing techniques kept the aircraft light in weight but still rugged and tough. Although the C-130 was a large aircraft for its time, it was designed to operate from marginal airstrips made of grass, soft dirt and even ice. Large, low pressure, tires in conjunction with powerful thrust reversing propellers and an effective antiskid brake system

gave the aircraft an excellent short field landing ability. The built-in versatility of the C-130 allowed it to be converted to meet the varied demands for airlift service in a matter of minutes. With simple modifications to the cargo compartment, the aircraft could quickly be configured for passenger and cargo hauling, airdrop and paradrop and even aeromedical evacuation missions.[4]

When the first C-130A was delivered to operational units in 1956 it could carry a payload of 36,600 pounds a distance of 1,830 miles. Its maximum cruising speed of 370 miles per hour and service ceiling of 34,000 feet far exceeded that of previous airlift aircraft. The ability to takeoff and land on 2,500 foot dirt or grass airstrips became the major operational difference between the C-130 and airlift aircraft that were to follow.[5] This significant element of mission versatility alone has maintained the Hercules as a mainstay of USAF airlift capability after 30 years of service.[6]

Designed to meet the needs of the Army Airborne Division, in its early years the C-130 could carry anything the 82nd or 101st Airborne Divisions planned to take to war.[7] The concept behind the C-130 development evolved from the airlift experience during the Korean War. Following the June, 1950 invasion, it took six long weeks to transport two Army divisions from the United States to the

Korean front. The C-54 Skymaster and C-124 Globemaster, piston engine strategic airlifters of that period, were sadly lacking in range/payload capability. The C-119 Flying Boxcar, C-46 and C-47 Gooneybird provided vital theater support to the tactical battlefield but could not accomodate all of the heavy equipment required by the front line forces.[8]

Thanks to its simple design and efficient use of technological advances, the C-130 effectively filled a void in the airlift system. This was not a time when airlift was at the forefront however. The national military strategy was massive retaliation and nuclear strike forces held the military's interest. It was not until 1964 that the airlift mission was even included in formal Air Force doctrine.[9]

By that time, President Kennedy had changed national strategy to flexible response. The multiple options implicit in this new strategy had a significant impact on the role airlift was to play in national defense... "the mobility mission of the Air Force took on new dimensions."[10]

On 23 April 1965 the first C-141 Starlifter squadron became operational. The turbofan jet powered C-141 offered a maximum payload of 70,847 pounds, service ceiling of 41,600 feet, and maximum speed of 571 miles per hour. The intertheater range of 6,040 statute miles, 3,965 miles with

design payload, provided the means for strategic deployment options which had been so painfully lacking at the time of the Korean invasion.[11]

Like the C-130, the C-141 was designed around the requirements of the Airborne Division, but offered significantly greater tactical airdrop capability.[12] Although the width of the cargo compartments was roughly the same, the C-141's increased length permitted the airdrop of 123 paratroopers compared to 64 for the C-130. Shortly after its introduction into active service, a C-141 set a world's record for heavy equipment airdrop with a single delivery of 70,195 pounds.[13]

As the scope of flexible response expanded so too did the demand for airlift. Along with the increased demand came a change in the nature of units and equipment to be deployed. Now the full spectrum of Army units was considered for possible deployment scenarios throughout the world.[14] As forces and equipment were modernized to counter the conventional threat, a gap in airlift capability surfaced. By late 1966, the C-141 was capable of transporting only 60-65% of major Army divisional equipment items.[15]

This deficiency did not stop the C-141 from proving its worth during the Vietnam conflict. When first deployed into the combat zone from the continental U.S. in August of 1965, the C-141 accomplished in 18 hours what it had

previously taken over 30 hours to do in a C-130. The C-141 force provided the bulk of the strategic logistics effort during the conflict which seemed to set new records for the amount of cargo and personnel moved in each succeeding six month period.[16]

The lack of the airlift system's ability to transport critical outsized cargo, such as the main battle tank, spurred the effort to acquire a multipurpose long endurance aircraft capable of carrying 100,000 pounds of outsized equipment up to 10,000 nautical miles without refueling.[17] This new conceptual airlifter evolved into the C-5A Galaxy, the world's largest aircraft.

After an accelerated development and acquisition program, fueled by the urgency of the outsize cargo requirement, the first C-5A was delivered to the United States Air Force in December 1969.[18] The C-5A possessed a design capability of 265,000 pounds maximum payload, 571 mile per hour maximum speed, and an 8,429 mile ferry range. With a 112,600 pound load of cargo the C-5A could transit strategic distances of up to 6,333 miles. The ability to land on short, unimproved runways of 4,000 foot length was to give the large airlifter unique mission flexibility.[19] The major operational advantage of the C-5A was its critically needed outsized cargo carrying capability.

Throughout the operational history of each of the described aircraft, numerous modifications have been made to improve their performance and versatility. An improved engine gave later models of the C-130 a maximum range/payload capability of 2,300 miles with 45,000 pounds of cargo. A range of 4,770 miles could be attained with a payload of 19,469 pounds.[20]

A major structural modification provided significantly greater capability for the C-141. Beginning in 1978, a program to "stretch" the aircraft and add air refueling capability to the entire fleet was initiated. By increasing each aircraft's length 23 feet 4 inches, room for three more cargo pallets and the air refueling receptacle was created. The 30% increase in cargo compartment size gave the Starlifter fleet a combined improvement in system capacity equivalent to the purchase of 90 additional aircraft. Coupled with the increased cargo carrying capacity, the greater mission flexibility achievable through air refueling greatly enhanced the C-141 mission versatility.[21]

As early as July 1969, five months before the first production C-5A was delivered to the Air Force, a design error was identified in the aircraft's wing structure. Further tests resulted in major operational restrictions being placed on the C-5A and a reappraisal of the expected service life of the airframe. In January 1980, after years of extensive fatigue testing, the Air Force awarded Lockheed

Corporation a contract for major wing modification to correct the design deficiency in the C-5A fleet.[22]

Unlike the C-130 and C-141 modification programs which improved each aircraft's versatility beyond design performance specifications, the C-5A wing modification was required in order to allow the aircraft to meet design specifications. The faulty wing design had restricted the C-5A to carrying a maximum of 80% of design payload and expected service life of the airframe had been reduced from 30,000 flying hours to 7,100 hours before the major wing modification was required.[23]

Each of the three modern airlifters has been highly promoted for its versatility. Each design marked a measured improvement over its predecessor. The varied capabilities complimented each other and together in an integrated, centrally controlled airlift system they have provided the basis for meeting the nation's time sensitive mobility requirements.

Overlapping capability has been a key element in the success of the system. Although none of the aircraft could completely span the spectrum of strategic and tactical requirements as General Tunner postulated, the flexibility gained from each expansion of individual capability was transformed into greater airlift system versatility.

Unfortunately, the increases in system capacity did not keep pace with the growing demand for airlift. Numerous

examinations of mobility requirements and system capability have been accomplished. Between 1975 and 1981, 17 different studies were undertaken culminating in the Congressionally Mandated Mobility Study (CMMS) in April 1981.[24]

The CMMS was the first study to examine all modes of mobility under different threat situations.

"It evaluated four scenarios:

(1) a Soviet-backed indigenous force attack of Saudi Arabian oilfields,

(2) a Soviet invasion of Iran,

(3) a NATO/Warsaw Pact conflict, and

(4) a two-front engagement which combined the scenarios in Southwest Asia and NATO."[25]

The results of the study led to recommendations for increased airlift, sealift, and prepositioned war supplies. Airlift capacity was to increase 20 million ton miles per day by fiscal year 1986. At least half of this increase in cargo carrying capacity was to be capable of hauling outsize items of equipment such as armored vehicles, large helicopters, and self-propelled artillery. "Further, the study group found that the ability to deliver cargo directly into austere, forward airfields would have a favorable impact on closure times by eliminating bottlenecks at main bases and reducing the requirement for intratheater transshipment."[26]

In 1983 the Air Force published the Airlift Master Plan which incorporated a series of corrective actions designed

to increase intertheater airlift system capacity from 32 million ton miles per day to the desired CMMS minimum goal of 66 million ton miles per day by 1986. Additionally, the plan incorporated findings from other studies which identified a shortfall in intratheater airlift as well. As a result of the total system analysis, Defense Guidance directed the Air Force to improve intratheater airlift capability by 50% before fiscal year 1989.[27]

Because of the seriousness of the strategic shortfall and the limited time available to institute corrective measures, the Department of Defense authorized the acquisition of 50 C-5B and 44 KC-10 aircraft in January 1982. Since both aircraft types were in current production, the time required to field new airlift assets was greatly reduced.[28] This acquisition, though critically important, was viewed as a stop gap measure and the cornerstone of the Airlift Master Plan was to be the development and acquisition of the C-17. Ultimately, the C-17 would replace the aging C-141 fleet, provide additional critical outsize capability and augment the C-130 in the intratheater arena.[29] The "direct delivery" concept is the C-17's challenge for greater mission versatility.

PROBLEM

Opponents of the C-17 question the need to pursue a costly development and acquisition program for a new airlift

aircraft. Although the need for increased system capacity is acknowledged, they suggest that the purchase of more aircraft currently in production, such as the C-5B and C-130H, would be far less expensive and still fulfill requirements.[30] The major point of contention is that the stated role of the C-17 sounds very much like that proclaimed for the C-5A almost twenty years ago. The 1967 C-5A Mission Statement states that the new airlifter had the capability to deploy combat forces over strategic distances directly into objective areas as far forward in the combat zone as the tactical situation required. This increase in delivery capability was based on the aircraft's short field takeoff and landing performance.[31] As the scope of its expected airlift role spread from strategic into tactical applications as well, the C-5A came to be envisioned as the most versatile airlift aircraft concept yet developed. Why, then, do we need the C-17?

Problems in the design, production, and acquisition processes have prevented the C-5A from completely fulfilling its original concept goals. While instituting the strategic role of the giant aircraft, the Air Force has discounted its intratheater applications by restricting its use to runways of at least 5,000 feet in length. Restrictions placed on the operation of the C-5A initially stemmed from its faulty wing design. Although Lockheed Corporation contends that

the C-5B with modified wings is capable of meeting original mission statement short field takeoff and landing criteria, the Air Force stresses that 16 years of operational experience has proven that the aircraft is not suited for austere airfield operation.[32]

In spite of its very controversial reputation, darkened by design problems and cost overruns, the C-5A has proven its worth as a highly effective strategic aircraft. In 1973, Operation Nicklegrass, the emergency Israeli airlift, provided the opportunity for the C-5 to validate its potential. During the 33 day crisis, the C-5 fleet operated at a 95% reliability rate, even though a severe spare parts shortage existed. The aircraft was the only means of ensuring that large, desperately needed combat equipment arrived in Israel in a timely manner. Additionally, had access to the refueling stop at Lajes Air Base, in the Azores, been denied; the C-5 was the only USAF airlifter which could have accomplished the non-stop flight between the U.S. and Israel.[33]

According to McDonnell Douglas Corporation the C-17 "has the performance versatility to fill the direct-delivery void that currently exists in the mobility equation."[34] Direct-delivery infers the requirement to transport cargo from source to user without transshipment. Since combat airlift's major user, the Army, is traditionally located away from major airfields, the ability to airdrop or airland

cargo on marginal, semi-improved delivery areas is essential. Thus the major impetus behind the C-17 is the ability to operate in and out of short, austere airfields with outsize cargo; the same objective which has eluded the C-5 in its quest for greater mission versatility.

PURPOSE OF THESIS

The purpose of this thesis is to determine if the C-17 is likely to achieve the mission versatility implied in the direct-delivery concept. To meet that end the thesis will address the following research questions:

1. Is the "direct-delivery" concept a valid airlift goal?
2. Can both the intertheater and intratheater airlift roles be encompassed by a single airlift aircraft design?
3. Have the lessons learned from the C-5A acquisition been incorporated in the development of the C-17 program?
4. How will the C-5 and C-17 development and acquisition programs influence future airlift aircraft design and acquisition?

LIMITATIONS

1. Documentation for this thesis will be restricted to that available in unclassified sources.
2. The comparison of aircraft capabilities in accomplishment of intertheater and intratheather airlift will not examine vulnerability to hostile actions.

The question of vulnerability of airlift assets in general and tactical airlift in particular is a very pertinent issue but beyond the scope of this study. A

number of recent research studies have addressed this issue.[35]

3. A complete analysis of aircraft performance will not be accomplished. Only those characteristics most controversial and vital to the accomplishment of each aircraft's stated intratheater role will be discussed.

ASSUMPTIONS

1. Official United States military strategy will continue to utilize both intertheater and intratheater airlift in the power projection role.

2. Mobility requirements for the movement of outsize cargo by airlift will increase as forecast.

3. The C-17 will meet the design performance standards presently stipulated by McDonnell Douglas Corporation.

METHODOLOGY

This thesis compares the effectiveness of certain aircraft performance characteristics in supporting airlift doctrine. Where limitations on C-5 desired performance are found; the cause for the deficiency is identified, its impact on mission versatility assessed and its correction or elimination in the development of the C-17 aircraft is documented.

Research was accomplished in the Fort Leavenworth Combined Arms Research Library. The scope of the research included airlift doctrine, governmental reports, military research studies, aircraft performance specifications, and published commentary on current airlift issues.

To assess each aircraft, five variables were utilized. First, the concept of operation for the aircraft

was evaluated. Then, the stated operational performance specifications established to fulfill the concept were examined. The resultant aircraft design and acquisition strategy were reviewed and finally, in the case of the C-5A, in-service mission performance was contrasted against the original role identified in the development concept.

ORGANIZATION

This study is divided into five chapters. Chapter II provides a review of the literature directly related to the problem. Chapter III is an analysis of the C-5A acquisition including lessons derived during its development and employment. The follow-on C-17 program is examined in Chapter IV and Chapter V contrasts the two programs, provides conclusions and recommendations.

SIGNIFICANCE OF STUDY

There is a substantial similarity in the conceptual airlift roles of the C-5 and C-17 aircraft. If the C-17 provides sufficient mission versatility to expand the existing airlift system capability then there is adequate reason to pursue its development. If, on the other hand, the C-17 fails to provide significant performance benefits above those of the C-5, then there is little justification for continued development. As the C-5A wing modification program is completed and C-5B production line started, more and more questions will be raised about the acquisition of

another airlift aircraft type. It is important to resolve those questions as early as possible in the development process.

DEFINITION OF TERMS

Airdrop	- The delivery of personnel, supplies or equipment by means of parachute.
Airland	- The delivery of personnel, supplies, or equipment by aircraft landing and manual downloading.
"Direct Delivery"	- The term used by McDonnell Douglas Corporation to describe the expanded airlift capabilities of their C-17 aircraft design. It implies the delivery of cargo from source to user, over intertheater or intratheater distances, without the need for transshipment.[36]
Outsize cargo	- Cargo which has excessive physical dimensions or weight that precludes its transportation on any Air Force airlift aircraft except the C-5.
Strategic Airlift	- The continuous or sustained air movement of units, personnel and material in support of all Department of Defense agencies; between area commands; between the CONUS and overseas areas; within an area command when directed. Strategic airlift resources possess a capability to airland or airdrop troops, supplies and equipment for augmentation of tactical airlift forces when required.[37]

Tactical Airlift	- The immediate and responsive air movement and delivery of combat troops and supplies directly into objective areas through airlanding, extraction, airdrop or other delivery techniques; and the air logistics support of all theater forces, including those engaged in combat operations, to meet specific theater objectives and requirements.[38]

CHAPTER 1 ENDNOTES

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[30] Benjamin F. Schemmer, "USAF, Asked Why Not an Updated C-5A Instead of New C-X, Reaffirms C-X Need," Armed Forces Journal, (April 1980): pp. 16-17.

[31] Jeffrey Denny, "The C-17's Uncertain Future," Military Logistics Forum, (January-February 1985): p. 66.

[32] Ibid., pp. 65-66.

[33] Comptroller General, Airlift Operations of the Military Airlift Command During the 1973 Middle East War (Report to Congress, April 1975): pp. 6-32.

34 McDonnell Douglas Corporation, "The New Direct-Delivery Airlifter," Airlift Operations Review, (January 1982): p. 12.

35 In February, 1981 the Military Airlift Command published the results of an in depth examination of tactical airlift, Close Look II. This study presented 139 individual proposals aimed at reducing tactical airlift vulnerability and improving operational effectiveness. By 1982, 84 of these had been implemented but many of the high cost advanced navigation and defensive systems recommended by the study still remain unfunded.

In a 1983 Air University Review article entitled "Doctrine by Default," Major Ron Boston concluded that the sophistication of enemy air and ground defenses may preclude future large operations. He also surmized that, in a high threat environment, smaller scale airlift operations are more likely to be effective because of increased difficulty of enemy detection and interception.

A 1983 Command and General Staff College masters thesis, C-X Operational Effectiveness in the Intratheater Environment, examined C-X vulnerability in a high threat European scenario. The author concluded that even though the C-X concept demonstrated significant improvement in survivability over previous airlift aircraft, its use should be restricted to operations no further forward in the combat zone than the division support area without installation of electronic counter measures equipment.

36 McDonnell Douglas Corporation, "The New Direct-Delivery Airlifter," p. 12.

37 U.S. Air Force, USAF Airlift Management Study (Confidential Study prepared by DCS/Plans and Operations, April 1970): pp. 18-19.

38 Ibid., p. 19.

CHAPTER 2

REVIEW OF RESEARCH LITERATURE

This chapter reviews the literature used in developing this thesis. Five categories of research material were used: government documents, books, periodicals, unpublished material and contractor information.

The modern airlift dilemma has its roots in the change of national strategy from nuclear retaliation to flexible response.[1] This bold initiative directed by President Kennedy in his inaugural address in 1961 was the basis for the rapid surge in mobility requirements over the past two decades.[2] The efforts to modernize the nation's airlift fleet in response to this growing demand culminated in two major strategic airlift aircraft design and acquisition programs; the Lockheed C-5A and the McDonnell Douglas C-17.

The C-5A, being the first major weapon system acquired under the Total Package Procurement System, has been much maligned for extensive cost overruns and design deficiencies.[3] Whether judged rightly or wrongly, extensive articles have been written about the C-5A, its acquisition, and the political and military decisions that guided its procurement.

The C-17, on the other hand, is currently in the spotlight of public scrutiny. Having evolved from the C-X program begun in 1980, less information is available on the proposed aircraft, however, the battle for acquisition approval has generated a significant amount of information from a number of credible sources, about the aircraft and its role in national strategy.

GOVERNMENT DOCUMENTS

Official military doctrine found in applicable regulations and manuals form the framework for the employment of air power. One of the primary United States Air Force missions listed in Air Force Manual 1-1, _Functions and Basic Doctrine of the United States Air Force_ is stated as "provide air transport for worldwide deployment."[4] AFM 1-1 further defines primary airlift tasks as "employment operations, strategic and tactical deployment of combat forces and equipment, logistics support and aeromedical evacuation."[5] This manual does not differentiate between strategic and tactical forces and defines the airlift mission in broad general terms. The specific tasks are spelled out in greater detail in other doctrinal documents.

AFM 2-4, _Aerospace Operational Doctrine: Tactical Air Force Operations - Tactical Airlift_,

stresses the combat orientation of tactical airlift forces. A major tenet of the tactical airlift mission is stated as the delivery of combat forces directly into an objective area."[6] Tactical airlift is tasked to routinely deliver personnel and supplies forward to brigade level and be capable of delivery to battalion and company level if the combat situation dictates.

The desire for a high degree of mission versatility and capability overlap is reflected in the manual's contention that "the multi-purpose aircraft organic to USAF tactical airlift forces pose continuing tactical and strategic threats to the enemy."[7] The manual further states that "when requirements of either tactical or strategic airlift forces are excessive, as may occur in large scale operations, the forces of one may be employed to augment the other in a mutually complementary role."[8]

The specific roles of strategic airlift are spelled out in AFM 2-21, United States Air Force Strategic Airlift. In addition to the primary intertheater mission, strategic airlift is tasked to augment tactical forces when necessary. Identified as essential elements of strategic airlift are "long range aircraft with the ability to augment other airlift forces in airland and airdrop operations in the combat zone and trained crews capable of executing all phases of airlift tasks."[9]

Another significant characteristic of strategic airlift is found in the manual's requirement for "a command and control system capable of controlling aircraft in such a manner as to realize maximum productivity and effectiveness from resources available."[10]

AFM 3-21, United States Air Force Strategic Airlift, further emphasizes the logistics delivery role of intertheater airlift. In maintaining the air line of communication (ALOC), strategic airlift is viewed as optimally delivering needed supplies directly from source to user. When operational constraints are taken into account, this forward delivery objective is modified to "as far forward as airfield capability permits."[11] Other objectives are employment of airlift aircraft with a high degree of mission flexibility and economic logistics delivery that minimizes aerial transshipments.

Joint doctrine concerning airlift centers around the deployment, employment and support of combat forces in the field of operations. FM 100-27/AFM 2-50, U.S. Army/ U.S. Air Force Doctrine for Tactical Airlift Operations, stresses the importance of immediately responsive airlift. While an air line of communication to division and brigade levels is established as the norm, capability to deliver to more forward echelons is required. A key difference between strategic and tactical airlift is that the tactical airlift mission is more closely related to the immediate needs of

the Army commander in the field. Having to adapt to shifting battlefield conditions, and other limitations, makes tactical airlift most frequently identified by numerous nonscheduled operations, many sorties of short duration, and a low aircraft utilization rate. Even though responsive airlift support often precludes it, efficiency of operation is viewed as a secondary objective of the tactical airlift system.[12]

The manual further explains that the main objective of the tactical airlift interface with the Army is to increase mobility. The goal of tactical airlift operations is to transport troops and material from the in-theater sources to the most forward destinations in the combat zone with a minimum of transshipments.[13] Being the foundation for tactical airlift support of the Army in the field, the manual also establishes the major operational characteristics necessary to adequately support the Army combat units as responsiveness, flexibility, and the ability to operate as far forward as possible in the combat zone.

The C-X Acquisition Program Request for Proposal (RFP) issued by the Air Force Aeronautical Systems Division outlines the Air Force's solicitation to the aircraft industry for competetive design proposals leading to the development of a new airlift aircraft. The RFP was forwarded to the Boeing Company, Lockheed Corporation and McDonnell Douglas Corporation for their use

in design and program formulation. The document explains in great detail the administration of the proposal process. Of primary interest to this study was the design guidance given the contractors and the factors evaluated in determining contract award.

In lieu of specified design criteria, the RFP established four operational airlift mission scenarios which the contractor was to solve by developing an analytical model. Each proposed aircraft would have to be capable of accomplishing the scenarios which varied from long range strategic resupply to short haul intratheater movement. Additionally, the C-X was tasked to interface with existing C-5, C-141 and C-130 assets in solving the model which incorporated realistic mobility requirements from 11 different Army and three Marine combat units. The RFP gave the contractor extensive freedom in design and focused on overall enhancement of the airlift system; not specific aircraft design criteria. General design guidance from the Air Force stipulated that the C-X was to be a rugged, reliable aircraft that would be simple to operate and maintain. Of utmost importance to the Air Force was the C-X capability to perform a wide spectrum of airlift tasks.[14]

The factors to be used in evaluating the proposals were: operational utility, mission scenarios, life cycle cost, design approach and program adequacy. The RFP clearly

stated that a development contract would not be awarded on the basis of price alone. In fact, undue complexity of design or technical risk in development was judged to be sufficient grounds for dismissal. Additionally, if a proposal was determined to be unrealistic in terms of costs, production schedule, technical merit or management commitments, evaluation penalties were to be assessed or the proposal rejected, depending on the severity of the findings.[15]

In August 1981 the Air Force announced that the C-X Source Selection Board had selected the McDonnell Douglas C-17 as the winner of the C-X competition. Four months earlier a proposal from Lockheed Corporation to restart production of the C-5 as an alternative to the C-X development had been rejected. The Air Force position was that the C-5 did not meet minimum C-X requirements.[16]

Because of similarities in the stated mission and capabilities of the two aircraft, controversy regarding which aircraft should be purchased soon developed. In response to a request from the chairman of the Senate Committee on Armed Services, the General Accounting Office investigated and published Performance Capabilities of the C-5 and C-17 Aircraft in July 1984.

The study reviewed the origin of the controversy starting with the initiation of the C-X program in 1979. It

analyzed the general capabilities of each aircraft presenting the Air Force's as well as the contractor's assessment of each. The comparison is focused towards examination of the capability to operate in and out of small, austere airfields which presumably would be necessary to reduce the present tactical airlift shortfall. The short field capability, or lack thereof, was found to be the heart of the controversy between the two aircraft.

An equally important finding was a disparity between the Air Force's and Lockheed's appraisal of C-5 capability. The differences centered around required takeoff and landing distances as well as ground maneuvering characteristics.

BOOKS

Little published material was found on either the C-5 or C-17 but this lack of published sources did not adversely affect the study.

Jane's All the World's Aircraft, edited by John W. R. Taylor, provided detailed information on aircraft performance, modifications and design history. This is a British publication which is published yearly with the latest specifications and developments in the world of aviation incorporated in one volume for easy reference.

Since both the C-5 and C-17 attempt to cross the doctrinal line between strategic and tactical airlift, a

review of airlift history is necessary to access the implications of new concepts and aircraft designs. Over the Hump, written by Lieutenant General William H. Tunner, describes not only the Himalayan airlift of World War II as the title suggests, but also chronicles the history of airlift through the eyes of its founder.

General Tunner traces the evolution of airlift from the birth of the Army Air Corps Ferrying Command in May 1941 up through his retirement from the Air Force in 1960. The general commanded the Himalayan "Over the Hump" airlift as well as the Berlin and Korean airlifts. Shortly before his departure from active duty, General Tunner was characterized as "Mr. Airlift" by Congressman L. Mendel Rivers, chairman of the House Armed Services Subcommittee.[17]

Through the general's recollections, the ideals that have become the hallmark of strategic airlift are seen to develop: efficiency, sustained logistics movement and economy of operation. The development of airlift doctrine is interspersed with telling vignettes.

In the latter part of his career, General Tunner enthusiastically promoted a two-phased airlift modernization program. The first phase produced the updated E model C-130 and the second phase led to development of the C-141 and eventually the C-5 aircraft.[18] Thus General Tunner not only provided the airlift community with a rich heritage of

leadership and doctrine but the current airlift fleet stands as his legacy.

Just as General Tunner describes the strategic side of airlift, Joseph E. Dabney provides the tactical message in Herk: Hero of the Skies. This book represents an extensive biography of the C-130, tracing its design, development and employment throughout the world.

Of particular note to this study was the C-130's contribution to the war in Vietnam. Dabney incorporates numerous quotes and first hand accounts from combat seasoned crewmembers who took part in classic tactical operations such as Khe Sanh, An Loc, the A Shau Valley and the Saigon evacuation. Through these testimonies, Dabney outlines the versatility and flexibility that the Hercules exhibited in a myriad of missions which he characterized as "the C-130's finest hour."[19]

A more detailed look at modern tactical airlift is found in United States Air Force in Southeast Asia: Tactical Airlift written by Ray L. Bowers. In addition to the employment history of intratheater airlift during the Vietnam Conflict, this work summarizes the decisions and actions which led to the consolidation of all Air Force strategic and tactical airlift assets into one command in 1974.

The book outlines how tactical airlift allowed United States forces to be concentrated in offensive roles.

An effective air line of communication was not only used as substitute for traditional land lines of communication but also allowed a reduction of defensive garrisons. The ready availability of combat airlift facilitated the Army's increased reliance on high mobility tactics.[20]

Stated as the most prevalent restriction on the effectiveness of tactical airlift in Vietnam was the availability and condition of forward airstrips. A critical element of any operations plan was the location and condition of an adequate C-130 airhead to support the proposed operation. Once the airhead was established, engineer efforts were vital in keeping the airstrip in commission as a steady stream of heavily loaded aircraft and enemy actions invariably produced signicient deterioration of the landing surface. In many cases this deterioration of airfield condition was so great that it placed continued airlift operations in jeopardy.[21]

Bowers also traces the impact of Project Corona Harvest, an Air Force study initiated midway through the war in an effort to gather and evaluate facts to be used in the development of future doctrine. The study had significant impact on command and control doctrine and recommended development of an advanced medium short takeoff and landing transport (AMST) to replace the C-130 in the tactical arena.

While the years of combat experience in Vietnam validated a need for expanded intratheater airlift

capability, the attempt to acquire a purely tactical replacement for the C-130 proved to be a futile effort. In 1972, the Boeing Company and McDonnell Douglas Corporation were issued contracts to develop prototypes of the AMST. Four years later the Boeing YC-14 and McDonnell Douglas YC-15 were flying in head to head competition aimed at acquiring the expected AMST production contract which was never issued.

PERIODICALS

In a 1966 article titled "The Revolution in Airlift" appearing in Air University Review, General Howell M. Estes, Jr. proclaimed the impending revolution in airlift capability to be attained by the acquisition of the C-5A Galaxy. General Estes set forth nine factors which he believed to be constraints on airlift and limits to its effectiveness. He then analyzed the characteristics of the C-5A which would allow it to overcome the nine constraints and thus revolutionize the airlift system.

General Estes deduced that a revolution in military airlift capability was necessary because of technological strides in communication and transportation which had reduced the world to one arena. He felt that the shrinking world placed greatly increased significance on one principle of war above all others; that of flexibility. In his view, airlift was the key to improving flexibility. "Global military airlift has been shown, throughout the era of the

cold war, to be a principal medium of achieving maximum military flexibility."[22]

In order to achieve the desired flexibility, General Estes postulated that an airlift aircraft had to overcome the historical constraints of the following interrelated and overlapping variables: speed, range/payload tradeoff, flexibility of employment, cubic capacity, loadability, self-sufficiency, terminal base requirements, fuel dependency, and direct operating cost. After contrasting C-5A capability against each of the nine variables, General Estes concluded that the only technological breakthrough that had been necessary to allow the C-5A to overcome the airlift constraints was the development of vastly improved, high bypass turbofan engines.

"Doctrine by Default" written by Major Ronald G. Boston, traces the origins of tactical airlift doctrine from its beginning with the troop carrier units of World War II. The article outlines the separate but parallel development of strategic and theater airlift forces. Major Boston documents that prior to the consolidation of all airlift resources into the Military Airlift Command in 1974, there was an extensive overlap in capability and equipment between intertheater and intratheater airlift forces. Today that dichotomy has been eliminated and the remaining overlap in capability allows one force to augment the other under a centralized command and control structure.

Major Boston is quick to point out that even though consolidation of airlift resources has meant centralized control and movement towards greater airlift efficiency, tactical airlift doctrinally remains a theater force directly responsive to the joint commander. The essential elements of tactical airlift that evolved from the lessons of past conflicts have not been altered by time or consolidation. Responsiveness and flexibility are still paramount. "The tactics have changed since World War II to match changes on the battlefield, but the doctrine that evolved remains intact."[23]

Writing in Airlift Operations Review, Lieutenant Colonel Neil Sorenson questioned the adequacy of strategic airlift dogma in his article "Airlift Doctrine: Is It Adequate for a High Threat, High Intensity War?" After an examination of the historical basis for current strategy airlift doctrine, Lt Col Sorenson surmises that future strategic applications of airlift will include a much greater power projection role. Current strategic airlift operational training is primarily based on fulfilling specialized logistics airlift requirements with little attention paid to the possible implications of having to operate in a hostile environment. Lt Col Sorenson suggests that mission training and doctrine should be updated to support strategic airlift's growing power projection role.

"We must stop stressing the role of MAC as a transportation operating agency and start emphasizing it as a power projection force."[24]

Edgar Ulsamer, senior editor of Air Force Magazine, documented the airlift shortfall in his article "Airlift: Key to Modern Military Mobility." Mr. Ulsamer presents the view that deterrence is based on the capability to project power and that power projection is dependent on adequate airlift. He points out that recent efforts to improve airlift capability have been extremely successful in three areas: the C-141 "stretch" program, C-5 wing modification, and elimination of the long-standing spare parts shortage throughout the airlift system.

Because of increased reliance on strategic airlift to implement national objectives, Mr. Ulsamer suggests a change in the orientation of strategic airlift doctrine is necessary. Since it is believed that airlift will supply only an estimated five percent of the required tonnage in the course of any future conflict, the advantages of airlift over other strategic supply alternatives such as sealift must be fully developed. Thus, in scenarios such as Southwest Asia where deployed forces may be almost totally dependent on airlift support for the first 30 days of an engagement, the traditional elements of tactical airlift, flexibility and responsiveness, take on a strategic application as well. The C-17 acquisition was determined

be the most likely course of action to fulfill the projected shortfall and changing role of military airlift.

Likewise, Colonel Thomas D. Pilsch argues for acquisition of the C-17 in "The Airlift Master Plan: Evolution and Implementation." Published in Defense Management Journal, this article examines the Air Force's proposed airlift enhancement program alongside the lift requirements specified in the Congressionally Manadated Mobility Study of 1981. The aircraft mix, system capability and estimated cost required to implement the Master Plan is examined in detail.

Colonel Pilsch supports the 1982 decision to purchase 50 improved C-5B and 44 KC-10 aircraft as a near-term corrective measure for declining strategic airlift capability. He states that this option will significantly enhance the airlift system because of the dramatic increase in outsize cargo and strategic air refueling capacity. The dual advantages of reduced cost and timely acquisition derived from the purchase of updated models of aircraft currently in production are equally important.

The C-17 acquisition, however, is viewed as the logical long-term airlift solution. Colonel Pilsch cites the aircraft's intertheater and intratheater outsized cargo delivery versatility, low estimated life cycle cost, minimum impact on manpower assets, and compatibility with airlift force modernization goals as the key arguments in favor of

the C-17. He emphasizes that the decision to procure the C-5B and KC-10 aircraft was not a judgment against the merits of the C-17 but a realistic acknowledgement of the critical nature of the overall airlift shortfall and the immediate need for vital strategic capability.

In "Airlift: Finding the Plane to Fit the Mission," Everett A. Chambers provides one of the two direct comparisons of C-5 and C-17 capability used by this study. This analysis, found in the November 1982 issue of Armed Forces Journal, additionally includes a short discussion of reliability, maintainability, and intratheater augmentation.

Mr. Chambers compares both the strategic and tactical capabilities of the two aircraft. In strategic applications, the C-5 was judged superior in payload/range capability, carrying slightly more cargo over greater distances. Over the average deployment range of 2,500 to 3,500 nautical miles, the C-5 was capable of approximately a 10 percent greater payload. The C-17 was determined to be vastly superior in the intratheater role, primarily because of its smaller size, better takeoff and landing performance, ground maneuverability, and interface with other airlift system components.

In assessing intratheater performance of the two aircraft, Mr. Chambers used the Advanced Medium STOL Transport program specifications as a base line for his

comparison. The C-17 equalled or exceeded C-5 performance in every area examined and provided the only realistic operational capability when the use of airfields less than 4,000 feet in length were considered.

A major finding of the comparison was the C-17's ability to overcome the inefficiency of the present airlift system which is caused by the need for transshipment when utilizing current intertheater and intratheater assets.

Jeffrey Denny describes the current airlift dilemma in "The C-17s Uncertain Future." This article in the February 1985 issue of Military Logistics Forum attempts to put opposition to the C-17 program in perspective. Arguments in favor of more C-5s as an alternative to the C-17 acquisition are examined and the reluctance of certain defense experts to back the C-17 program is reviewed.

Mr. Denny explains that some members of the defense establishment believe the C-17 is the result of a last minute effort by the Carter Administration to create the impression that the airlift problems associated with the Rapid Deployment Force concept had been solved. Additionally, the high initial development cost of the C-17 is stated as a major argument used by proponents of the C-5 alternative for the improvement of airlift capacity. He points out that even though C-17 development costs are estimated at $4 billion and total acquisition cost is expected to be $37.5 billion, the life cycle cost over the

aircraft's expected 30 year operational life span is $4 billion less than the C-5 option. When compared on a one to one basis, aircraft costs are virtually the same. The C-17 is expected to cost $178 million per aircraft while the new C-5B will costs $177 million each.

The major stumbling block for the C-17 program may not be the C-5 option however. Mr. Denny suggests that in the fight for dwindling defense acquisition funds, the C-17 might be overshadowed by larger strategic enhancement programs such as the MX missile and B-1 bomber. If so, the cheaper short-term acquisition cost of the C-5 could outweigh any qualitative performance difference between the two systems. He remains confident, though, that the C-17 will withstand the opposition and cites continued funding of the research and development phase of the C-17 program as evidence of a commitment to institute the direct delivery concept.

UNPUBLISHED MATERIAL

A large number of research studies relating to this topic were identified in the course of research. Most were student projects from intermediate and senior service schools and spanned the period from 1960 to the present.

An Air War College research paper written in 1977, Evolution of Airlift Doctrine, provided a wealth of background information. The author, Lieutenant Colonel Jimmie L. Jay, traces the development of strategic and

tactical airlift doctrine from the mid-1930s through 1977 when MAC became a specified command.

The major thrust of this document is the ascendency of strategic airlift at the expense of tactical doctrine. The author contends that the lessons of the Korean and Vietnam conflicts were not adhered to as combat and combat support functions were allowed to merge. The resultant strategic orientation of the airlift force remains today.

Additionally, Lt Col Jay documents the Army's efforts to improve organic airlift capability on occasions when the Air Force's tactical airlift capability was allowed to decline. He concludes that assigning an intratheater role to a strategic airlifter, such as the C-5; at the expense of the development of dedicated tactical airlift capability, could cause the Army to seek increased organic airlift once again. In other words, the duplication of airlift assets and redundancy of command and control elements that existed prior to airlift consolidation in 1974 could be repeated if the Air Force's tactical airlift force modernization efforts are not pursued with the same vigor as its strategic initiatives.

<u>Tactical Airlift: A Mission in Search of Doctrine</u>, by Lieutenant Colonel Harvey D. Chace, is another Air War College paper closely paralleling the above document. Lt Col Chace concludes that most of the present tactical airlift doctrine has evolved from the recurring

process of resolving conflicts over roles and mission issues between the Army and Air Force. He suggests that an integrated tactical fighter, airlift and Army approach is necessary to produce joint doctrine in support of combat logistics.

Lt Col Chace states that current airlift doctrine is not adequate because it failed to keep pace with the Army's shift from a strategy of "active defense" to the AirLand Battle concept. Not only is the tactical airlift force insufficiently equipped to meet the increased logistics demand but "the tempo of AirLand Battle may seriously challenge the responsiveness of today's interservice airlift request system."[25] Much of the disparity in operational capability is due to a somewhat independent development of each service's mission, doctrine and weapon systems. "The overriding need to develop joint doctrine to perform joint operations outweighs the requirement to operate unilaterally."[26]

Intratheater Airlift - Mission Impossible? also concludes that a closer working relationship between the Army and Air Force is necessary. In this Air War College research report, Lieutenant Colonel Marvin S. Ervin states that ill-defined requirements coupled with widespread modernization of Army combat equipment has led to a serious void in intratheater airlift capability. He proposes that the C-17, or similar intratheater airlift aircraft with

outsized cargo capability, is needed to fulfill present mobility requirements.

The author bases his support of the C-17 concept on his assessment that other proposed solutions such as the acquisition of more C-5B aircraft, increased reliance on prepositioning of materials configured to unit sets (POMCUS), and expansion of the civil reserve air fleet (CRAF), place an even greater burden on already overly tasked in-theater assets by greatly increasing the need for transshipments. In his view, the direct delivery aspect of the C-17 will reduce saturation at theater logistics terminals and greatly reduce the time necessary to transport war materials from source of supply to user. To ensure maximum system efficiency is achieved and maintained, closer coordination between Army and Air Force planners is an absolute necessity.

In The Airlift Lessons of Vietnam - Did We Really Learn Them?, Major David C. Underwood examines 15 recommendations, concerning airlift, extracted from the Project Corona Harvest reports of 1965 through 1969. He found that while a certain degree of success has been achieved through the incorporation of nine of the findings into the current airlift system, key areas of concern, such as inadequate facilities at forward airstrips and development of a follow-on tactical airlifter, remain unresolved.

In order to evaluate the status of the Corona Harvest recommendations, Major Underwood studied after action reports from joint exercises and contingency operations such as Reforger, Jack Frost and the Zaire airlift. He also reviewed current doctrinal manuals and regulations as well as historical documents and interviewed Military Airlift Command staff action officers. After extensive analysis, Major Underwood concluded that there are "inherent dangers associated with viewing history from a lessons learned perspective, particularly in search of patent recipes and answers to future unknowns."[27]

Two studies of the C-5A acquisition program were found to be of particular merit. One, a masters thesis titled History and Analysis of the C-5A Program: An Application of the Total Package Procurement Concept, thoroughly examines the C-5A acquisition. The authors, Major Jerry V. Poncar and Captain James R. Johnson II, found the total package procurement process to have been fairly effective in achieving contract performance even though the concept was extremely controversial in its C-5A application and later publicly disowned by the Defense Department. The Air Force's failure to adequately evaluate Lockheed's cost estimates and an accelerated contract definition phase were identified as the major shortcomings of the C-5A acquisition program.

Colonel William H. Loomis examines the same program with somewhat different conclusions in an Army War College research paper titled The C-5A Acquisition Process: Myth or Muff? He characterizes the C-5A as a technological success that was unfairly criticized for its high cost. In Col Loomis' opinion, the two billion dollar overrun that blighted the program was attributable to the highly inflationary economic climate which existed during the aircraft's development and acquisition. In his view, the spiraling costs were unavoidable and definitely not a fault of the total package procurement process.

C-X Operational Effectiveness in the Intratheater Environment, a masters thesis by Major Donald M. Desert, Jr., addresses the design capability of the C-17 conceptual airlifter to operate in a European wartime environment. By comparing design specifications to a set of standard operational measures, assimilated from the performance characteristics of other airlift system aircraft, the author derives C-17 expected performance. As stated in Chapter One, Major Desert also assesses the C-17's vulnerability to hostile actions in a high threat environment. He concludes that the C-17 should prove to be effective in the intratheater role but a revision of existing doctrine will be necessary to achieve its integration into the airlift system.

Majors Steven D. Acuff and Jeffrey L. Wise examine both the strategic and tactical implications of the C-17 acquisition in a research report titled Introduction of the C-17 into the Military Airlift Command Airlift Force. The report takes a more detailed look at the aircraft's affect on material handling equipment requirements, cargo on-load and off-load efficiency, and ground handling characteristics. The authors identified two major limitations on the effectiveness of the current airlift system, transshipment requirements and the lack of ability of certain aircraft to utilize smaller intratheater airfields. It is their contention that the C-17 will overcome those limitations and propel the airlift system to new levels of flexibility and responsiveness.

CONTRACTOR INFORMATION

This category of literature, although used sparingly in this study, provides an abundant amount of technical data for the researcher. The competition for the C-5A contract alone generated 35 tons of documents from the five major airframe and power plant manufacturers.

Of particular interest was The Lockheed C-5: Case Study In Aircraft Design prepared by Wilfred G. Garrard, Senior Research and Development Engineer for Lockheed-Georgia Company. This case study is divided into two sections; the first a narrative of the design process

and the second, a notebook of technical airframe specifications. The study is a concise history of C-5A development beginning in October 1961 with the Air Force's Qualitative Operational Requirement for a C-133 replacement and extending through the delivery of the 81st C-5A in May 1973.[28]

Mr. Garrard explains the design alternatives that were considered in the development of the C-5A and outlines the rationale behind the selected configuration. He also summarizes the performance tradeoffs that were made because of cost, technological limitations, the effect of other design requirements and the accelerated acquisition schedule. The narrative provides a chronological view of the aircraft's development and proved to be extremely valuable in the evaluation of the C-5A acquisition.

SUMMARY

The heart of the problem facing the C-5 and C-17 in their respective attempts at increased mission versatility is the inherent differences between strategic and tactical airlift. An examination of the level of airlift system technology and recent endeavors aimed at crossing the doctrinal division between the two airlift roles indicates that the problem is a multi-faceted one. Changing doctrine or increasing technology alone will not solve the problem.

The first major difference between the two roles is obvious; one is directly combat related while the other is oriented towards combat support. One is based on providing immediately responsive battlefield flexibility and the other on efficiencies of scale, designed to achieve sustained support over time. The environments each is required to operate in are markedly different as well. These varied environments in turn dictate a certain set of aircraft performance charcteristics. To date, the combination of these variables has effectively precluded any single aircraft type from completely encompassing the breadth of capability necessary to merge the two traditional airlift roles.

The growth of the intertheater and intratheater airlift elements under separate command structures also had a significant effect on the problem. On one hand, the diverse commands attempted to promote the unique aspects of their own mission at the expense of the other and fostered a divergence of mission responsibilities in order to maintain organizational parity. On the other hand, each side of the divided airlift structure developed and acquired aircraft with expanded levels of performance which allowed them to infringe on the other's doctrinal turf. This development and implementation of overlapping capability led to the logical conclusion that the merging of the two roles was

not only possible but highly desirable from the standpoint of efficient resource utilization.

The consolidation of airlift resources into the Military Airlift Command in 1974 was a direct application of the above logic. Although centralized control of airlift has provided greater efficiency, the command still relies on the overlapping capability of three distinctively different aircraft types to accomplish the two separate roles. To put the present situation in perspective, it must be pointed out that C-5 development and acquisition took place before consolidation. As such, it represents the last vestige of the old, dual command system which left the existing airlift force, tied together through overlapping capability, as its legacy.

The C-5, then, represents the efforts of a purely strategic airlift command to develop a strategic airlifter which could increase strategic preeminence by making moderate inroads into the tactical arena. Being the first airlift development program since consolidation, the C-17 represents a genuine attempt to combine both roles and has attacked the problem from the ground up, rather than seeking a solution by the historical means of add on capability.

CHAPTER 2 ENDNOTES

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CHAPTER 3

THE C-5

CONCEPT

The origins of the conceptual airlifter which was to become the C-5A Galaxy evolved from a change in national military strategy from that of massive retaliation to flexible response. As early as 14 June 1960, in a foreign policy address before his colleagues, Senator John F. Kennedy announced his serious reservations about the ability of the nation's military to support worldwide national objectives.

> "We must regain the ability to intervene effectively and swiftly in any limited war anywhere in the world -- augmenting, modernizing, and providing increased mobility and versatility for the conventional force and weapons of the Army and Marine Corps. As long as these forces lack the necessary airlift and sealift capacity and versatility of firepower, we cannot protect our commitment around the globe..."[1]

The expanded scope of the airlift mission coupled with the age and capability of the existing fleet caused senior defense officials to seriously doubt if airlift could provide the required mobility. Since responsive airlift was critical to his new strategy, President Kennedy emphasized the urgent need for airlift modernization in his 30 January 1961 State of the Union Message.

"I have directed prompt action to increase our airlift capacity. Obtaining additional airlift mobility -- and obtaining it now -- will better assure the ability of our conventional forces to respond with discrimination and speed, to any problem at any spot on the globe at any moment's notice. In particular, it will enable us to meet any deliberate effort to avoid or divert our forces by starting limited wars in widely scattered parts of the globe."[2]

In response to the direction to obtain greater airlift capacity, the Air Force issued a Qualitative Operational Requirement (QOR) for the replacement of the Douglas C-133 Cargomaster. This replacement was envisioned to be a multipurpose, long endurance aircraft with a strategic range of 4,000 nautical miles and a 100,000 pound outsize cargo carrying capacity. Design engineers within the Air Force Systems Command refined the QOR and produced a Specific Advanced Development Objective which stated that the replacement airlifter should be "capable of carrying 100,000 pounds, 10,000 nautical miles without refueling, using laminar flow control (LFC) techniques and regenerative high by-pass turbofan engines.[3]

As the operational concept of the new airlifter evolved, critics began to question the need for a new type of airlift aircraft in lieu of the large quantity of recently developed C-141 Starlifters which were just beginning to enter active military service. This criticism apparently significantly affected expansion of the C-5's

mission concept. In an attempt to delineate a distinct operational advantage over the C-141 and other airlift aircraft, the conceptual C-5 got bigger and better.

In an address before the House Armed Services Committee on 18 February 1965, Secretary of Defense Robert S. McNamara attempted to justify the acquisition of the C-5. He stressed that recent inclusion of C-130 and C-141 aircraft into the airlift inventory had greatly improved system capability but a very large capacity airliner was still needed to bolster the nation's strategic deployment posture. Additionally, Secretary McNamara informed the committee that a technological advancement in jet engine performance now allowed the development of a 725,000 pound class aircraft which would be more economical to operate than any of the existing airlift aircraft, able to transport the bulkiest pieces of Army equipment over intercontinental distances and deliver them well forward in the theater of operation.[4]

Thus, in roughly four years of extensive study, design development and congressional lobbying, the C-5 concept had grown from that of a large, strategic airlifter capable of hauling outsize cargo into that of a very large, highly efficient and economical aircraft capable of spanning the doctrinal division of intertheater and intratheater airlift. Or at least that was the concept in the minds of certain defense department officials and congressmen.

REQUIREMENT

In June 1963, the Air Force issued a statement of Specific Operational Requirement (SOR) for the CX-X. The CX-X, also termed the CX-4 and CX-HLS in the conceptual development phase, was to be operational in the airlift system during the 1968-1980 time period. It was estimated that 167 such aircraft would be required to meet the growing demand for airlift.[5] A listing of the major stipulations of the 1963 SOR can be found in Appendix A.

Shortly after the issuance of the June 1963 SOR, a great debate over the proposed aircraft erupted. On one side, General Bernard A. Schriever, Commander, Air Force Systems Command, suggested that the program should take full advantage of developing technology which would lead to a maximum unrefueled range capability of 10,000 nautical miles but would require an Initial Operational Capability (IOC) date of late 1971. On the other, General Joe W. Kelly, Military Air Transport Service commander, stressed the urgent requirement for increased airlift system capacity and a willingness to accept lower range performance as a trade off for an IOC date no later than 1969. After much turmoil the 1969 Initial Operational Capability date was adopted.[6]

In April 1964 the Air Force issued the CX-HLS Request for Proposal (RFP) to five aircraft airframe and three engine manufacturers. On 5 June, Boeing, McDonnell

Douglas, Lockheed as well as General Electric and Pratt & Whitney were selected to perform further concept formulation. Findings from these studies were incorporated in the 12 December 1964 RFP for development of the C-5A.[7] Major elements of the RFP are listed in Appendix B.

It is significant to note the major changes from the 1963 SOR. Maximum required payload capability had increased from 150,000 pounds to 265,000 pounds. Range with 100,000 pound payload had increased from 4,000 nautical miles to 5,500 nautical miles. Take-off distance at maximum gross weight had increased from 8,000 feet to 10,000 feet and although the requirement to land on a 4,000 foot runway with a 100,000 pound payload remained, range requirement for a subsequent mission was reduced from 4,000 nautical miles to 2,500.

Even though a compromise in range performance had been made to speed up the acquisition of the C-5, it appeared that developing laminar flow control and propulsion technology would boost the giant airlifter's capability well above that of the C-141. When compared to the C-141's maximum payload capability of 70,847 pounds, the C-5's orginial 150,000 pound outsize capability might not have been enough to warrant development; a 265,000 pound capability would be.

ACQUISITION

In April 1965, Boeing, McDonnell Douglas and Lockheed submitted their proposals for CX-HLS development to the Air Force. Lockheed's cost estimte of $1945.38 million for the 115 C-5A airframe production program was $400 million less than the Boeing proposal and significantly less than the Air Force's independent cost estimate of $2240 million. After a four month examination the Air Force System Source Selection Board (SSSB) determined that each proposal failed to meet the takeoff and landing requirements established in the RFP. On 1 September that announcement was made to the manufacturers and the SSSB requested that revisions to the proposals be made within three days.[8]

The Boeing proposal required only the change of a takeoff flap setting while Lockheed's revision incorporated an untested design change to the aircraft wing. After reviewing the revisions to the proposals, the System Source Selection Board recommended the selection of the Boeing proposal for C-5A production contract award.[9]

Both Boeing Company and McDonnell Douglas Corporation were in the midst of large commercial production programs. Lockheed, on the other hand, was expected to close its Marietta, Georgia facility as the C-130 and C-141 programs wound to a close. It can be speculated that cost, idle production capacity and the recent history of two successful airlift aircraft production runs influenced the

contract award decision. For whatever reason, the Department of Defense awarded the C-5A airframe contract to Lockheed on 30 September 1965.[10]

The contract issued on 1 October 1965 called for production of five test and 53 production aircraft with options for an additional 142 aircraft under two follow-on provisions. Being the first major system acquisition contract released under the Total Package Procurement Concept, it was a fixed priced contract which held the contractor accountable for expected levels of aircraft performance as well as price and production schedule compliance.[11]

The Total Package Procurement Concept was designed to remedy the inadequacies of the defense weapons acquisition process which had been historically riddled by cost overruns averaging 220%.[12] The causes of the overruns were suspected to be "single year appropriations which limited efficient planning of programs and the Cost-Plus-Fixed-Fee (CPFF) contracts which provided little incentive for contractor efficiency."[13] By fostering greater competition in the acquisition process, proponents of the Total Package Procurement Concept, felt they could achieve increased system efficiency and reduce excessive defense spending.[14] Retaining all three airframe contractors throughout the contract definition phase of the acquisition process had stimulated competition and reduced

the time necessary to accomplish source selection. The selection of Lockheed to produce the C-5A, based on its technically inadequate design proposal, however, sacrified any benefit gained from the increased competition upon which the system was based. [15]

The major problems attributable to the Total Package Procurement Process as it affected the C-5A acquisition were lack of contract flexibility and concurrency.[16] The contract managers within the Air Force held fast to specified performance standards and program schedule milestones with little or no negotiation when the contractor experienced design problems. The result of this inflexibility caused Lockheed to make design and managerial decisions which ultimately degraded the performance of the aircraft. The urgency placed on the development and acquisition of the C-5 led to the concurrency problem; initiation of production prior to the solution of design and development inadequacies.

The procurement process was further ravaged by the effects of inflation. It is generally accepted that extensive program cost increases were unavoidable regardless of the contractor selected or the acquisition process used. The stringent requirements on meeting specified price and performance standards made any cost growth shamefully apparent, regardless of the cause.[17] Thus the downfall of the Total Package Procurement Process

was precisely what it was designed to prevent; uncontrolled cost in defense weapons acquisition.

In spite of all the problems throughout the acquisition process, the first C-5A was delivered to the Air Force in December 1969. The initial operational capability date had been met, but cost and performance suffered.

DESIGN

There has been a great deal of discussion about the original design objectives of the C-5A. As the Statement of Requirement and Request for Proposal indicated, the major operational function which drove the design requirements was the outsize cargo capability. When expectations of that capability grew from 150,000 pounds to 265,000 pounds, the required gross weight of the aircraft ballooned well above the initial objective of 600,000 pounds. Although the technology to build such a mammoth aircraft was thought to be available, the false assumption that the C-5A would merely be a scaled-up C-141 overlooked the complex production problems inherent with the larger aircraft.

From the beginning of the project, Lockheed waged an intensive battle to control the weight of the aircraft. The revision to the April 1965 proposal might be viewed as the beginning of the downfall of Lockheed's design. In order to meet the landing criteria in the RFP, wing surface area had to be increased by 6,200 square feet and trailing edge flaps

increased by 6 percent in size. These changes in wing design alone resulted in an increase of takeoff gross weight from 685,000 to 712,000 pounds.[18]

The untested design change produced severe drag problems. In an effort to bolster the performance of planned high lift devices, Lockheed incorporated the use of full-span Handley Page slats and Fowler flaps. Eventually, the magnitude of the air disruption problems forced Lockheed to acquire expensive subcontract work in England. A number of the drag problems were solved by the addition of streamlined fairings, but these corrective measures also increased aircraft weight. In 1966 Lockheed began intensive negotiation aimed at the reduction of several performance requirements which in turn would allow relief from the growing aircraft weight problems. For the most part, the specifications of the 1965 contract were maintained and Lockheed received little relief.[19]

The unresolved design problems coupled with the inflexibility of the contract which demanded strict compliance in the accomplishment of performance and production schedule milestones provided the environment for the most critical decision in the C-5's development. Having been notified that failure to meet specified performance requirements could constitute grounds for contract termination, Lockheed deviated from the required wing structure material thickness in order to reduce aircraft weight.[20]

Because of concurrency, the design flaw that this deviation created was not identified until July 1969, five months before the first production C-5 was delivered to the Air Force. Testing continued, but the full extent of the wing structure problem was not fully appreciated until August 1979 when a panel of experts determined that damage caused by the design flaw was so extensive that the service life of those affected C-5's should be reduced from 30,000 to 7,100 flying hours.[21]

From its initial entry into active service, the C-5A was plagued by uncertainty over the extent of its design problem. The aircraft was utilized less than planned in order to stretch its service life over a longer period. Normal inventory levels of spare parts were not acquired for fear of a major modification requirement which might make them obsolete. Operational restrictions were placed on the aircraft in an attempt to limit the growth of stress cracks which resulted from the design flaw in the aircraft wing. Two major C-5 operational policies were the restriction of the aircraft to only 80% of design cargo carrying capacity and operation on hard surface runways at least 5,000 feet long and 150 feet wide.

The 80% cargo capacity restriction still allowed the C-5 to demonstrate a marked improvement in versatility over the C-141. The outsize cargo capability alone was enough but the 374% greater payload capacity and improved range

rapidly established the C-5 as the preeminent strategic airlift aircraft. The aircraft's failure to fulfill its short-field operational ability is another question however.

There is evidence that the concept behind the C-5 development did not envision the broad short-field capability that has been attributed to the aircraft.[22] The SOR and RFP specified a limited 4,000 foot takeoff and landing capability as well as landing gear requirements to enable operation on unprepared or semi-prepared surfaces associated with support area airfields. There were no requirements, such as a backing or combat offload capability, to suggest that extensive operation into these support area or intratheater airfields was envisioned. Failure to address taxiway, ramp and loading support requirements indicate that this aspect of operation was not seriously addressed.

When asked why the C-5 had been restricted from using semi-prepared austere airfields and limited to those hard surface runways of at least 5,000 foot length, Dr. Hans Mark, Air Force Secretary, stated:

> "Originally, we thought C-5s would be able to do that (operate from small, austere fields), but we were wrong. Operational tests with the C-5 plus analyses of several inadvertent departures from paved surfaces showed so much damage to the airplane as well as to the airfields that C-5s have been restricted to prepared runways."[23]

More light can be shed on the C-5's attempt at greater mission versatility by reviewing statements made by Mr. Everett Chambers. Mr. Chambers was chief of the Airlift Operational Requirements Branch of the Air Staff from 1975 through 1979. Additionally, he spent five years working airlift requirements on the Military Airlift Command Staff from 1963 to 1968 and another five years in the C-5 test program.

Commenting on the C-5's design objectives Mr. Chambers infers that the defense weapons development and acquisition process in the mid-60s was not as sophisticated as it is today. In his view, the C-5 SOR was not as well defined as it should have been, primarily because of a failure to completely analyze the airlift system requirements as they related to the new airlift concept. In retrospect, SOR design specifications were driven almost totally by takeoff and landing performance alone while other critical aspects, such as ground maneuvering and interface with existing airlift system facilities, were ignored.[24]

LESSONS LEARNED

The first and probably most obvious lesson is found in the proposed role of the aircraft. Though the requirement behind the development of the C-5 was clearly to fill the outsize cargo capability void and provide urgently needed strategic mobility, its collateral or secondary

function of being able to land on 4,000 foot runways and deliver cargo as far forward as operationally feasible was not adequately developed. A quote extracted from the 1970 USAF Airlift Management Study best addresses this issue.

> "While it is often expedient to capitalize on aircraft design overlap (capability and versatility), it does not follow that the responsibility for roles and missions ought to be based on such hardware overlap."[25]

The proposals submitted by competing manufacturers during the contract definition phase are extremely important. Less than adequate execution of this phase severely affected the C-5A product. One of the major conclusions reached by Major Poncar and Captain Johnson in their thesis, History and Analysis of the C-5A Program: An Application of the Total Package Procurement Concept, was that "...the most significant error in the C-5A program was the apparent disregard for the major products of the definition phase."[26] By accepting Lockheed's revised proposal only three days after the original had been rejected because of a failure to meet specified design and performance standards, the Air Force effectively discounted the nine months of effort by the approximately 500 engineers who were to eventually develop and produce the aircraft.[27]

In evaluating the C-5A acquisition it is important to re-emphasize that the Boeing proposal was selected by the System Source Selection Board over that of Lockheed. The

bids submitted by each contractor were: Boeing, $2,300 million; and Lockheed, $1,946 million. Since the Air Force's own independent estimate was $2,240 million for a 645,000 pound aircraft, the legitimacy of Lockheed's bid, based on a 732,500 pound gross weight aircraft, should have been questioned.[28]

The total package procurement concept did not dictate that the production contract be awarded to the lowest bidder. Instead it stipulated that the contract be given to the competitor whose price and performance commitments were judged to be the most cost effective over the product's operational life.[29]

Once the contract was awarded, inflexibly holding Lockheed to specified performance standards only perpetuated the contractor's design problems. If a negotiated settlement could have been achieved early in the program, the serious wing design deficiency which plagued the aircraft might have been eliminated.

> "When the contractor and procuring activity determine that the selected acquisition strategies are unsuitable for a given problem, they have a mutual responsibility to revise the strategies and renegotiate any related contractual provisions. By continuing with unsuitable acquisition strategies or contractual instruments, neither the contractor nor the Government can deal effectively with system performance problems that arise."[30]

The last lesson learned from the C-5A acquisition was the undesirability of concurrency. Proceeding with full

scale production before a design, that was known to be questionable at best, had been thoroughly tested and validated allowed 40 aircraft to be put into operation with a critical design flaw. The zeal in which the defense establishment pursued the 1969 IOC date led to concurrency even though the results of contract definition should have suggested it was an unwise strategy.

> "While program concurrency may speed up the acquisition process, its use can prevent the disclosure of design deficiencies or other problems until substantial amounts of production hardware have been accepted. Concurrency, therefore, increases the risks of costly modifications to obtain desired performance characteristics. The use of concurrency should be limited -- preferably to those system acquisitions whose technology is at hand or whose urgent military need has been validated."[31]

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CHAPTER 4

C-17

Concept

In 1966, a study to evaluate the effectiveness of Air Force airpower employed in Southeast Asia was initiated. Tasked to develop specific "lessons learned"; Project Corona Harvest was to provide recommendations to be used by future Air Force commanders.[1] A major portion of this study was dedicated to an evaluation of airlift operations.

Tactical airlift was at the forefront in Vietnam. Highly flexible, responsive, intratheater airlift provided the catalyst for a strategy based on rapid mobility. Probably the best example of the timely application of airlift resources occurred during the Tet Offensive of 1968. Tactical airlift delivered as much as 92,500 tons of critically needed supplies per month in response to the changing demands of the battle. Approximately 70 percent of that resupply effort was carried by the workhorse C-130.[2]

In order to defeat widespread communist attacks, intratheater airlifters additionally repositioned tens of thousands of combat troops and sustained their operations in remote locations by airlanding and airdropping thousands of

tons of ammunition. This continuing airlift sustainment effort was vital to the Army's ability to turn the course of the battle since, in many cases, the enemy had thoroughly severed the ground lines of communication. The constant requirement for tactical airlift support in the austere areas of the combat zone, missions the C-141 and C-5 are not capable of accomplishing, came to be a fact of life throughout the course of the conflict.[3]

Unquestionably the most memorable airlift operation in Vietnam was the resupply of the encircled Marine garrison at Khe Sanh. From 21 January to 8 April 1968, tactical airlift flew 1,128 sorties delivering 12,430 tons of vitally needed food, fuel, ammunition and construction material.[4] Without continuous intratheater airlift support, the garrision could not have withstood the siege. Transporting the critically needed supplies 99.9 percent of the way from the United States to Khe Sanh in strategic airlift aircraft would have been for naught if tactical airlift, capable of sustained operations into and out of the austere combat environment, had not been available to insert the munitions and supplies directly into the battle.[5]

One of the major Corona Harvest findings was that a follow on airlift aircraft with short takeoff and landing (STOL) capability was needed to replace the aging tactical airlift fleet.[6] The rigors of combat employment had extracted a heavy toll on the aircraft involved. Lockheed

experts estimated that C-130s operating in Vietnam incurred ten times greater wear and tear than like aircraft operating outside the combat zone over the same period.[7]

Boeing and McDonnell Douglas were issued contracts in late 1972 to build and test prototypes of a new, rugged, wide body tactical airlift aircraft. The program was designated the Advanced Medium Short Takeoff and Landing Transport (AMST). Four years later, the Boeing YC-14 and McDonnell Douglas YC-15 performed as technology demonstrators in an Air Force fly off competition.

President Carter deleted AMST program funding from the budget in January 1978 and on 10 December 1979 the program was officially cancelled.[8] The primary reason behind the program cancellation was the AMST's lack of ability to transport large payloads over strategic distances.[9] Congress and senior decision makers demanded greater mission versatility.

> "Advocating a single purpose, point design tactical airlift airplane in the defense budget process turned out to be a no-win situation. Washington is a town that operates on finite numbers; putting such a number or series of numbers on the requirements and benefits of in-theater airlift is a significant and, as it turned out, impossible task. The Air Force would be hard pressed in today's analytical environment to justify the large numbers of C-130s currently in inventory. To advocate a tactical airlifter which cannot perform the total airlift mission is tilting at windmills in the Washington competition for defense dollars."[10]

On the very same day the AMST was cancelled, Department of Defense Program Management Directive RC0020(1)

initiated the C-X program. Unlike the intratheater AMST, however, the C-X was conceived primarily as an intertheater, strategic aircraft.[11] A joint service C-X Task Force examined the aspects of military airlift in detail in order to identify the aircraft characteristics needed to facilitate rapid force projection. This study, completed in June 1980, was released prior to the Congressionally Mandated Mobility Study but close coordination within the Department of Defense assured their compatibility.[12]

So, the C-X concept of a strategic airlifter which was capable of augmentation in the intratheater role evolved from the inability to gain support for the purely tactical AMST. The AMST had at least gained the Army's support though. In a 1977 study of tactical airlift requirements for the Army during the mid-1980 period, the Combined Arms Combat Development Activity concluded: "It is essential that tactical airlift have the capability to carry the main battle tank."[13]

The change from a tactical to strategic orientation was merely a sign of the times. President Carter was concerned with fielding the MX missile, Air Launched Cruise Missile (ALCM), and Trident II submarine. Another developing concept was the "rapid deployment force."[14] Once again, strategic issues held the military's interest.

As recognition of the expanding strategic airlift shortfall grew, it was the direct relationship with the AMST

program which distinguished the C-X concept from other proposed solutions. The atmosphere surrounding the program's acceptance demanded strategic capability. The CMMS was to validate a tactical role as well. Thus, another conceptual airlifter was attempting to bridge the gap between intertheater and intratheater airlift.

REQUIREMENTS

The efforts of the joint service C-X Task Force resulted in a Preliminary System Operational Concept (PSOC) which outlined the intended purpose, employment and deployment options, as well as support requirements of the C-X.[15] This in turn was translated into the C-X Request for Proposal (RFP) which was released to the aircraft industry in October 1980.

The C-X RFP broke the traditional practice of stipulating specific performance standards such as maximum gross weight, payload capacity, size, or takeoff and landing distances. As an alternative, the RFP provided a set of tasks to be performed by the C-X working in conjunction with the existing airlift fleet. These tasks encompassed the broad range of airlift mission characteristics including types of personnel and cargo to be moved, distances involved, as well as, onload and offload base restrictions. The objective of the RFP was to define a problem, give the aircraft industry as much freedom as possible in developing

an aircraft to solve the problem, and provide incentive for the increase of performance based on a reduction of life cycle costs.[16]

The problem, or tasks to be performed, was divided into four mission scenarios which paralleled those used in the CMMS.[17] Each scenario had a troop listing of different Army and Marine units complete with cargo transport requirements, including outsized. Additionally, a time limit was placed on the accomplishment of each scenario in conjunction with a specified mix of C-5, C-141 and C-130 aircraft. A depiction of the four mission scenarios is located in Appendix C.

The different scenarios of the C-X RFP were specifically designed to eliminate the inefficiency encountered with the existing airlift force. Much of that inefficiency was a result of the need for transshipment.[18] Because C-5 and C-141 ground operations are limited by the physical dimensions of certain runways, taxiways and parking ramps, the RFP was very specific about the ground environment in which the C-X would have to perform. Specifications for main operating base (MOB), forward operating base (FOB), and short, austere airfield (SAAF) are depicted in Appendix D. These definitions were determined to be representative of the airfield structure used in the current airlift system.

While these mission scenarios and airfield descriptions drove most of the design requirements for the C-X, one other critical area of concern was specified in the RFP. In an attempt to avoid the design and development costs of a new system, the C-X was required to utilize a commercially available Federal Aviation Administration certified power plant.[19]

ACQUISITION

In January 1981, the C-X Source Selection Evaluation Board took receipt of proposals from Boeing, Lockheed and McDonnell Douglas. The board evaluated the proposals based on "operational utility, mission scenarios, life cycle cost, design approach, and program adequacy."[20] The operational utility evaluation was deemed the most important. Of primary significance was the proposed aircraft's effectiveness in performing operational missions, ruggedness, and dependability while operating in austere environments.[21] The McDonnell Douglas design, later designated the C-17, was declared the winner of the competition in August 1981.

Acquisition of the C-17 is being pursued under a "fly - before - buy" concept implemented because of experiences encountered in the C-5A program.[22] Full scale engineering development is scheduled to begin in FY 86 and the first flight is scheduled for December 1989. The

tentative initial operational capability date is early 1992.[23]

The C-17 contract includes warranty provisions covering reliability, availability, and maintainability. The warranted level of performance is higher than that of the three current Military Airlift Command airlifters. "The airframe is warranted for 10 years or 10,000 hours and the landing gear components for twice that time."[24] If a structural defect is encountered in the 45,000 hours of required durability testing, the contractor is obligated to correct it as part of the warranty agreement. The contract also provides incentive payments for surpassing program goals.

The Airlift Master Plan recommends the acquisition of 210 C-17 aircraft; 180 of which are to be acquired prior to 1998. It also specifies the C-17s as a replacement for the C-141 fleet whose phase out of active service is scheduled to begin in the mid-1990s and extend slightly beyond the year 2000. While the 1982 decision to purchase 50 C-5B aircraft is viewed as an expedient stop gap measure, the C-17 acquisition will allow achievement of the long term CMMS goal for both intertheater and intratheater airlift.[25]

DESIGN

There are five design elements of the C-17 that provide the foundation for its versatility: size, wide body

profile, externally blown flaps, direct-lift control spoilers, and directed flow core thrust-reversing engines. The combination of these elements make the C-17 a truly unique aircraft.

The C-17 has a length of 170.7 feet and a wing span of 165 feet, roughly the same as a C-141B, yet it can haul outsize equipment previously only transportable by the C-5.[26] The wide body design permits the loading of two 5 ton trucks side by side in the cargo compartment. A total of 16 pallets of cargo may be carried by the C-17 and 40,000 pounds, more cargo weight than is usually carried by a C-130, can be transported on the loading ramp alone.

Externally blown flaps in conjunction with direct-lift control spoilers provide the basis for the C-17's excellent short-field capability. The blown flap technology entails the directing of engine exhaust over and through the aircraft wing flaps in order to create additional lift. The high, forward position of the engines, required to facilitate exhaust flow over the flap assemblies, also provides the added benefit of increased ground clearance. This feature is significant in terms of obstacle avoidance and the reduction of the risk of foreign object damage to the aircraft engines. The direct-lift control spoilers, mounted on the upper wing surfaces, improve the low speed handling characteristics of the aircraft. The operational advantage of this combination of

externally blown flaps and direct-lift control spoilers is the reduction of approach airspeed to as low as 115 knots in an aircraft carrying a maximum cargo payload and sufficient fuel for a 500 nautical mile return flight.[27]

The C-17's engine thrust-reversers not only reduce landing ground roll distances but also permit ground maneuvering on small, austere airfields. The directed flow of the thrust-reversers reduces the hazard of jet blast to other aircraft and personnel while maneuvering, provides a vital backing capability and greatly decreases the probability of ingestion of debris by the engines.[28]

The technology behind these design elements has been successfully demonstrated by the YC-15 in the AMST competition. Over 800 flying hours and 8,000 hours of wind tunnel testing validate the design. A large percentage of the aircraft subsystem equipment comes off the shelf from other already proven programs making the C-17 development a "straight forward application of fundamentals."[29]

CHAPTER 4 ENDNOTES

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4 C.E. Watts, III, Aerial Resupply For Khe Sanh -- 21 January - 8 April 1968 (Research Report, USA Command and General Staff College, March 1972): pp. 16-17.

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9 Thomas D. Pilsch, "The C-X Requirement: Perspective on Airlift," Airlift Operations Review, (January 1981): p. 9.

10 Everett A. Chambers, "Airlift: Finding the Plane to Fit the Mission," Armed Forces Journal, (November 1982): p. 41.

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12 Thomas D. Pilsch, "The Airlift Master Plan: evolution and implementation," Defense Management Journal, (Fourth Quarter, 1984): pp. 27-28.

13 U.S. Army, Advanced Medium STOL Transport (AMST) Study, Executive Summary (Prepared by the Combined Arms Combat Development Activity, August 1977): p. 2.

14 Jack J. Catton, "Evolution," Airlift, (Winter 1984): p. 7.

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[16] Pilsch, "The Airlift Master Plan," p. 27.

[17] Donald M. Dessert, Jr., C-X Operational Effectiveness in the Intratheater Environment (MMAS Thesis, USA Command and General Staff College, 1983): p. 19.

[18] Pilsch, "The C-X Requirement," p. 10.

[19] Chambers, "Airlift," p. 46.

[20] U.S. Air Force Systems Command, C-X Request For Proposal (RFP) Volume I (April 1980): Annex M, pp. 2-3.

[21] Ibid.

[22] Comptroller General, C-5A Wing Modification: A Case Study Illustrating Problems in the Defense Weapons Acquisition Process (Report to the Subcommittee on International Trade, Finance and Security Economics, Joint Economic Committee, March 1982): p. 79.

[23] Pilsch, "The Airlift Master Plan," p. 31.

[24] Edgar Ulsamer, "The Airlift Master Plan," Air Force Magazine, (May 1984): p. 65.

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CHAPTER 5

COMPARISON

Both the C-5 and C-17 attempt to achieve increased airlift versatility by crossing the doctrinal boundary between strategic and tactical airlift. The biggest challenge to each aircraft's attempt to fulfill this dual role concept is the physical limitations of the intratheater environment itself. In the C-5 development, a detailed examination of theater airfield characteristics was not accomplished.[1] The expanded capability of the C-5 was based solely on a limited 4,000 foot takeoff and landing capability coupled with a landing gear designed to permit operation on other than paved surfaces.

The C-X Task Force was the first group to extensively examine the characteristics of runways throughout the free world.[2] Their 1979 study documented the relative scarcity of long strategic runways outside the United States. Only 1,576 runways were found having a minimum of 5,000 foot length and 150 foot width. The study also noted that as runways decreased in length they and their associated taxiways became narrower, parking ramps became smaller and load bearing capacity decreased.[3] Thus the C-5, which was designed to operate on a NATO standard runway, 8,000 feet long and 150 feet wide, is seriously

limited in gaining access to the smaller airfields generally associated with intratheater operations. In central Europe alone the C-5 is normally restricted to 46 of the 710 available runways surveyed by the C-X Task Force. See Appendix E for an analysis of the survey findings.

This assessment of world wide runway characteristics was translated into the airfield descriptions found in the C-X Request for Proposal. The main operating base (MOB), deployment operating base (DOB), forward operating base (FOB), and short, austere airfield (SAAF) definitions incorporated the results of the 1979 study along with expected deployment and employment criteria affecting airfield utilization. This approach caused the C-17 to be designed from the ground up in order to meet the demands of the intratheater environment.

The airfield assessment identified factors other than runway length which could restrict aircraft utilization. Although the C-5's capability to land on 4,000 foot runways would seem to imply an intratheater role, the immense size of the aircraft, wide turning radius during ground maneuvering and lack of a backing capability drastically reduces the number of airfields it can use. Since the physical limitations of intratheater airfields were taken into account during C-17 development, it will achieve far greater accessibility to short, austere airfields. The C-17 will be capable of operating into and

out of a minimum of 9,887 of the surveyed airfields compared to 1,576 for the C-5.[4]

A major determinant of airfield operational accessibility is runway and taxiway width. Short, austere airfields are generally found to have a runway width of 90 feet and taxiway width of 50 - 60 feet. The C-5's minimum 180 degree turning radius is 148 feet and it requires taxiways of 75 feet in width for ground operations. The C-17, on the other hand, requires only 82 feet to make a 180 degree turn and will routinely operate on 50 foot wide taxiways.[5] The backing capability provided by directed flow thrust reversers will also enable the C-17 to easily maneuver into the constrained parking areas usually present on smaller airfields. See Appendix F for a comparison of ground maneuvering capabilities.

Air Force contingency planners consider 193,000 square feet of paved ramp space to be the minimum parking surface requirement for a C-5.[6] In many cases, this required ramp area exceeds that available at smaller airfields. The ramp size for SAAFs in the C-X RFP was established as 75,000 - 120,000 square feet and ramp size of FOBs was only 250,000 square feet. On these airfields the C-5 is severely restricted by its size and lack of maneuverability. Even on a 500,000 square foot ramp, nine C-17s can be parked in the same space required to accomodate two C-5s. See Appendix G for a parking requirement

comparison. The flexibility the C-17 demonstrates once it is on the ground is also a very important factor in evaluation of its strategic effectiveness.

A major criticism of the C-17 when compared to the C-5 has been its reduced cargo carrying capacity. On the surface a design payload difference of 130 tons for the C-5 and 86 tons for the C-17 seem very significant. When comparing payload capability over strategic distances of 2,500 - 3,500 nautical miles, however, the C-17 achieves approximately 90% of the C-5's cargo capacity. Additionally, since an airfield of any size can support a greater number of C-17s than C-5s at any given time, the strategic objective of maximizing cargo delivered over time can be judged roughly equivalent; the C-5 getting the edge on efficiency and the C-17 on flexibility. Turn to Appendix H for a comparison of range and payload capability.

Because of the tradeoff of reduced aircraft size for increased accessibility to intratheater airfields, the C-17 will not quite match the C-5's gross cargo carrying capability but will gain a great deal in terms of increased mission versatility and flexibility.

SUMMARY

A sense of urgency pervaded the C-5 acquisition from the start. The major doctrinal change from a national

strategy of massive retaliation to that of flexible response fueled the immediacy by creating extensive demands for airlift in support of a heightened conventional military posture. The concept of the C-5's airlift role was allowed to expand as an expedient to the attainment of defense acquisition approval while design engineers struggled to apply developing technology to facilitate the ambitious concept goals. An apparent disjunct developed between the C-5's stated concept of operation and the design criteria specified in documents such as the 1961 Qualitive Operational Requirement and the 1963 Specific Operational Requirement. The end product failed to meet the expanded conceptual goals. There are three reasons for this divergence in the C-5's airlift role.

First, when faced with opposition to the development of the C-5 so soon after the C-141 acquisition, proponents had to vigorously promote increased mission versatility in order to gain acceptance of the new aircraft. To gain support, the key characteristic of outsize cargo capability was embellished with increased range, payload, cost efficiency, as well as takeoff and landing performance aimed at giving the C-5 a marked improvement in operational effectiveness over the C-141.

In translating these performance goals into aircraft design specifications, Air Force planners did not fully take

into account all of the factors impinging on the expanded role. Intratheater capability was tied to runway performance and little attention was directed towards the effect of other airlift system variables on design requirements. As a participant in the SOR development stated, "we did not fully understand the systems aspect of the mission as well as we should have..."[7]

The final factor influencing the role divergence was the urgency surrounding the acquisition. In order to fill the void in airlift capability as rapidly as possible, the commander of the Military Airlift Command and other key defense officials were willing to sacrifice expected higher performance levels in exchange for speedier production and delivery. Since the new national strategy was extremely dependent on strategic mobility, their objective was clearly to increase capability as rapidly as possible.

The C-17 development has proceeded along similar lines but with major differences. Like the C-5, the C-17 concept has evolved to satisfy a shortfall in strategic airlift capacity. Unlike the problem encountered with President Kennedy's major national defense policy change, which drastically increased airlift requirements almost overnight, the concept behind the C-17 has been established to meet the continued growth in airlift requirements over the past two decades. Both strategic and tactical roles were envisioned for the aircraft from the beginning.

Although the present airlift shortfall is just as critical to national military preparedness, the urgency behind the need for C-17 acquisition has been attenuated by the procurement of 50 C-5B and 44 KC-10 aircraft as a short term solution to the inadequacy of airlift resources. Alleviated of any compelling immediacy, the C-17 development has proceeded along a more realistic timetable.

As in the C-5 development, a major link between the C-17 concept and actual mission performance is technology. Although developing laminar flow control and high by-pass turbofan engine technology was expected to support the C-5 concept, the decision to pursue development without thorough testing of industrial capability had a negative effect on anticipated aircraft performance. The C-17 received the majority of the technology necessary to implement its concept from the successful AMST competition winner, the YC-15. The design elements used to provide the C-17 intratheater capability have been demonstrated and thoroughly evaluated during 800 flying hours of the YC-15. Unlike Lockheed, which had to contract outside assistance to solve C-5 airflow problems, McDonnell Douglas has proven the operational feasibility of the C-17 design.

Additionally, concurrency will not disguise technical problems as its use did in the C-5 development and acquisition process. By acquiring the C-17 under a fly-before-buy strategy, hidden design faults should be all

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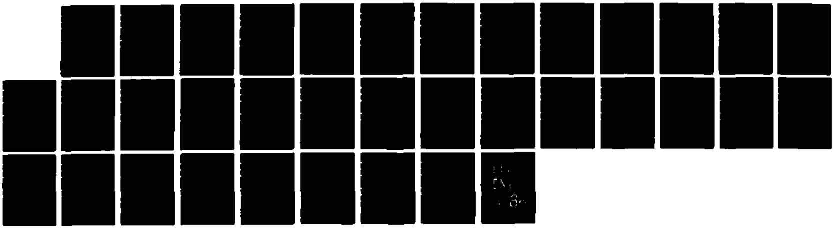
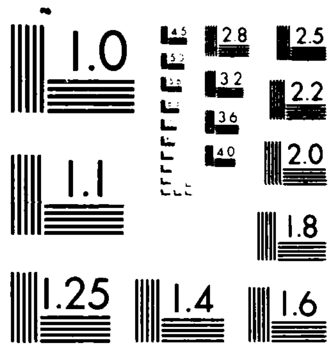




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

but eliminated. Warranted performance levels are to be demonstrated prior to the Air Force acceptance of the aircraft and the contractor is responsible for the correction of any identified deficiencies. This strategy should prevent the duplication of events which allowed cost overruns in the C-5 program to develop into economic losses that threatened to exceed the net worth of the corporation itself.

With the development of the C-17 it is clear that General Tunner's advice is being followed. The primary force behind this quest for greater versatility and a reduction of aircraft types has been the drive for economy and efficiency of operation instilled by the defense acquisition process itself. If it cannot demonstrate a significant operational advantage over its predecessor, its chances of further development are minimal. When others have opted for specialized capabilities, the defense acquisition process steadfastly demands increased versatility. The results of this procedure are sometimes ambiguous. Even the tactical C-130 assault airlifter emerged from the process labeled as having strategic capabilities.

Airlift doctrine also supports the move towards greater versatility. It appears that, since the beginning of airlift, the strategic and tactical elements have shared overlapping responsibilities. This overlapping capability

was a natural phenomenon when intertheater and intratheater airlift forces were controlled by different commands. With the consolidation of all USAF airlift resources into the Military Airlift Command in 1974, centralized control moved the Air Force one step closer to General Tunner's goal. It is little wonder that the first major airlift aircraft development program initiated since consolidation incorporates both an intertheater and intratheater role.

CONCLUSIONS

The "direct-delivery" concept is a valid airlift goal. It is precisely the ultimate development necessary to allow a complete realization of national military objectives by providing the vehicle to quickly project a tailored combat force anywhere in the world and sustain that force. The concept is not necessarily a new one however. Although not specifically stated as an explicit end objective, the concept has been nurtured by preceeding attempts at greater airlift versatility.

The emergency Israeli airlift in 1973 clearly demonstrated the vulnerability of a strategic airlift system heavily dependent on a highly developed infrastructure of transshipment points, refueling locations, and support bases. Even in instances short of conflict, U.S. ability to

pursue national interest could be thwarted by an ally's political decision to temporarily revoke basing or overflight rights. In a time when U.S. global commitments tend to diverge from our major allies' more regional outlook, it seems prudent to move towards self-sufficiency. A "direct-delivery" airlift capability is a move in that direction.

The C-17 will be able to span the airlift spectrum. Previous attempts by other aircraft have been restricted from achieving that goal, first, by the differing demands of the operational environments and, second, by the lack of technology to adequately meet those demands. Of the two different roles, intratheater operations place the greatest demands on aircraft performance. In attempting to design an aircraft capable of fulfilling the demands of both operational environments, it seems logical to address the more restrictive one first.

In retrospect, the method by which C-5 developers approached the dual-role problem, giving a strategic aircraft tactical applications, was as much responsible for the failure of the aircraft to meet its expanded conceptual goals as any other factor in its development. By thoroughly analyzing the intratheather environment and adopting the proven technology of an intratheater prototype, the C-17 designers and planners are attacking the problem from the

proper direction and have a much greater probability of successfully achieving their goal. The C-17 will not be the single answer to all airlift needs however. It will meet General Tunner's desires by being able to accomplish any type of transport mission but, even today, the restrictions of the operating environment and technology must be balanced against each other and the C-17 represents a compromise to meet that end.

The compromise in capability stems from the highly developed concept of operation envisioned for the C-17 from the very beginning. In order to achieve the "direct-delivery" concept, certain tradeoffs have to be accepted. Critics of the aircraft, who denounce it because of a payload capacity that is lower than the C-5's, do not fully recognize the problem to be solved. All the cargo capacity in the world is of little value if that cargo cannot be delivered where it is needed in a timely and efficient manner. The C-17's performance specifications, then, represent a realistic approach toward the achievement of its airlift goal.

The lessons learned in the C-5A acquisition have been incorporated in the develop ent of the C-17. The first lesson, the undesirability of basing an aircraft's airlift role merely on overlapping capability, has been corrected through the C-17's innovative design development. Secondly, the acceptance of an unproven, unrealistic aircraft design

has been avoided because of the indirect benefit of the AMST program development and eventual cancellation. Third, the potentially severe problems which could occur as a result of program concurrency have been eliminated by the fly-before-buy acquisition policy now in effect. It remains to be seen, however, if the fourth major lesson learned from the C-5A acquisition, that of contract inflexibility, will be avoided in the C-17 program.

The C-17 contract is to have warranted performance specifications and incentives for increased aircraft performance resulting from contractor initiative. Least we forget, the C-5A had similar contractual clauses but their inclusion did not guarantee acquisition of an aircraft which fully met established performance goals. In fact, a failure to negotiate changes to the contract specifications when the contractor's ability to meet them was in serious doubt only served to seal the fate of a troubled program. The key to this point, then, is that the marriage of the military to major defense contractors in the weapons systems acquisition process should not be an adversarial relationship. Both parties must work together toward a common end. Although it can be speculated that C-17 acquisition will take advantage of increased contract flexibility, only time will tell if this lesson has been fully implemented.

The contrast of the two different acquisition processes will undoubtedly affect future airlift aircraft

development programs. Because of the high cost involved in major acquisition programs, concurrency is most likely a thing of the past. Likewise, the establishment of airlift roles primarily based on add on capability should not be repeated. The C-17 approach to design formulation will probably be adopted in any following development of airlift resources.

Once the C-17 completely validates the "direct-delivery" concept through operational acceptance, future aircraft development will unquestionably lean toward a multipurpose concept as well. The primary driving force behind this orientation will be the demand for efficient resource utilization within the defense weapons acquisition process and the factor which will lead to its fruition will be increasing industrial technology.

RECOMMENDATIONS

In both the C-5 and C-17 programs, airlift is responding to growing demand for its services. It has been stated that we can never have too much airlift and we can never afford to have the amount we need. It is paramount, then, that we develop, utilize and maintain these resources wisely.

Just as increased capability, such as an outsize cargo delivery vehicle for the intratheater environment, is vital to adequate combat logistics support so too is the

predictable development of combat equipment and doctrine. In order for airlift to remain effective, aircraft must not be made obsolete by an unchecked growth in combat equipment size or doctrinal employment objectives.

The joint service C-X Task Force is only one of many inroads made towards the solution of this problem. Efforts must be steadily applied, however, to ensure that airlift capability and planned employment objectives remain compatible. Listed below are recommendations that address the problem area.

- A detailed analysis of the Army's requirement for airlift of outsize equipment to forward areas in the combat zone, under the AirLand Battle doctrine, needs to be accomplished.

- Increased coordination between Army and Air Force action offices on major weapon system acquisition programs and employment doctrine changes needs to be implemented.

- An evaluation of the airlift request network and its adaptability to the C-17 "direct-delivery" concept needs to be accomplished.

RECOMMENDATION FOR FUTURE STUDY

This thesis has addressed the impending increase in airlift system versatility to be achieved by implementation of the "direct-delivery" concept and acquisition of the C-17

aircraft. Introduction of the C-17 into the present airlift system will undoubtedly tax command, control, and communications networks beyond current capabilities. Further, study is necessary in these areas to ensure timely corrective action and to facilitate efficient initiation of "direct-delivery" airlift operations.

CHAPTER 5 ENDNOTES

1 Everett A. Chambers, "Airlift: Finding the Plane to Fit the Mission," Armed Forces Journal, (November 1982): p. 41.

2 Steven D. Acuff and Jeffrey L. Wise, Introduction of the C-17 into the Military Airlift Command Airlift Force (Research Report, Air Command and Staff College, March 1982): p. 75.

3 Ibid., p. 73.

4 Edgar Ulsamer, "The Airlift Master Plan," Air Force Magazine, (May 1984): p. 62.

5 General Accounting Office, Performance Capabilities of the C-5 and C-17 Cargo Aircraft (Report to the Committee on Armed Services, United States Senate, July 1984): pp. 8-13.

6 Ibid., p. 13.

7 Chambers, "Airlift," p. 41.

A P P E N D I C E S

Appendix A

1963 CX-X SOR SPECIFICATIONS

1. Basic Design Mission (L.F. 2.5): Payload 100,000 - 130,000 lb. for 4,000NM.

2. Alternate Mission: Payload 50,000 lb. for 5,500NM.

3. Structural Capability: 130,000 - 150,000 lb. payload.

4. Cruise Performance: Not less than 440 KTAS and 30,000 ft. cruise altitude.

5. Take-off and Landing (over 50 ft): T.O. - 8,000 ft. at S.L. at 89.5 degrees F at maximum gross weight, 4,000 ft. on standard day with fuel for 4,000 NM. Landing - 4,000 ft. with 100,000 lb. payload and fuel reserves for 4,000 NM mission.

6. Airfield Requirements: Land on Rear or Support Area Fields.

7. Personnel Accommodations: Galley and latrine facilities for 25 people, 15 hours; oxygen for 25 people, 5 hours.

8. Cargo Compartment: Length 100-110 ft.; Width: 16-17.5 ft.; Height: 13.5 ft.; Two rows palletized cargo (2-88 in. or 1-88 in. and 1-108 in.)

9. Loading: Straight through loading
   Primary orifice to permit maximum use of the full fuselage cross section.
   Secondary orifice not less than 9 ft x 10 ft.
   Truck-bed height cargo floor desirable.

10. Power Plant: Six turbofan engines either military qualified or FAA certificated by June 1967.

11. Reliability: 95 percent probability of completing 10 hour mission.

12. Maintainability: Per MIL-M-26512 which required quantitative treatment.

13. Availability: No later than June 1970.

SOURCE Wilfred C. Garrard, The Lockheed C-5: Case Study in Aircraft Design (Case Study, Lockheed-Georgia Company, undated), p. 1.

Appendix B

1964 CX-HLS RFP SPECIFICATIONS

<u>Payload-Range</u>

Payload (lb.)	100,000	200,000	265,000
Range (NM)	5,500	2,700	2,700
Limit (L.F.)	2·5-1·0	2·5-1·0	2·25-0

<u>Take-off over 50 ft. at S.L. at 89·5 degress F.</u>

At Basic Design Gross Wt.(2·5g) 8,000 ft.

At Max Design Gross Wt. (2·25g) 10,000 ft.

<u>Landing Over 50 ft. at S.L. at 89·5 degrees F</u>

With 100,000 lb. payload and fuel to return at midpoint of 2,500 NM radius mission 4,000 ft.

<u>Initial Cruise Altitude</u>

At basic design gross weight 30,000 ft.

<u>Long Range Cruise Speed</u> 440 KTAS

<u>Propulsion</u>

Four turbofan engines with a sea level static thrust of 40,000 lb.

<u>Cargo Provisions</u>
Cargo Compartment Size:

Width, min. 17·5 ft., Length, min. 120 ft., excluding ramps

Floor area, min. 2300 sq. ft. excluding ramps, 2700 sq. ft. including ramps

Height, min. 13·5 ft (13 ft. min. width at 13·5 ft. height)

Cargo Accomodations:

Compatible with 463L ground and aerial delivery systems

Forward Ramp:

Full cross-section exposure.

Ramp angle 11 degrees
Aft Ramp:
Straight-in opening 13 ft. wide and 9·5 ft. high

Clearance normal to ramp 12 ft.

Ramp angle 13·5 degrees

Floor height for loading between 48 and 54 in.

Landing Gear
Flotation of 100 take-offs and landings without airfield repair, on Support Area Airfields (M-8 landing mat on CBR 4 sub-grade) at gross weight for landing with 200,000 lb. payload, fuel for 1000NM. range, tire deflection 40%. Cross wind pre-positioning from parallel to 20 degrees. Capable of 180 degrees turn on runway 150 ft. wide.

Reliability
90% of aircraft dispatched must reach their destination without a major subsystem failure. An additional 8% may suffer failures which do not cause a mission abort. A realiability level of 87% based on subsystem failure is to be demonstrated during the Category II (USAF) test program.

Maintainability
Quantitative maintainability requirements based on a minimum operational availability of 75%.

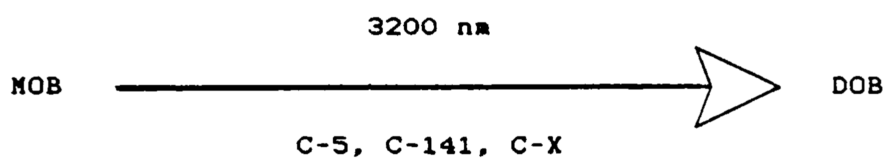
Airframe Life
30,000 hours of anticipated usage, including 6% at 300 ft. altitude at 350 KIAS using terrain avoidance. 12,000 landings, 5950 pressurizations.

SOURCE Wilfred C. Garrard, The Lockheed C-5: Case Study in Aircraft Design (Case Study, Lockheed-Georgia Company, undated), p. 16-17.

Appendix C

Depiction of mission scenarios used in the C-X Request for Proposal.

Mission 1: Mid-Range with Air Refueling Available

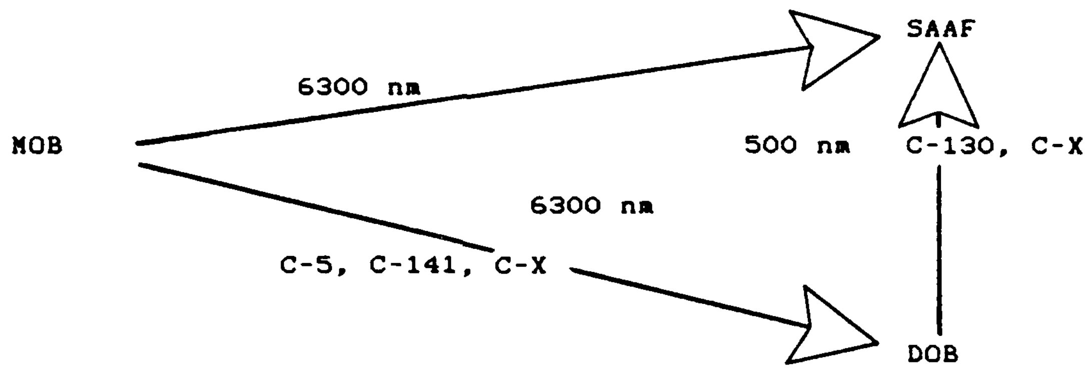


138,000 Tons in 11 days

Daily Missions Available

C-5	48
C-141	119
C-X	TBD

Mission 2: Long-Range, Non-Stop, with Air Refueling Available.

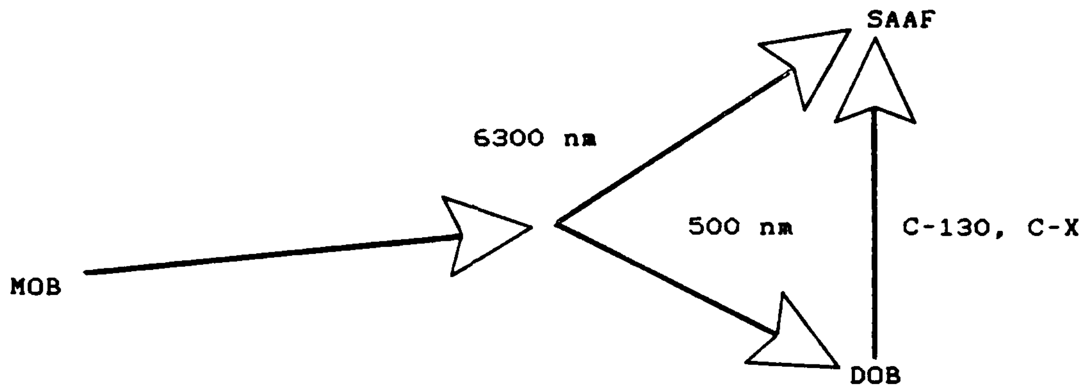


265,000 Tons in 25 days

Daily Missions Available:

C-5	25
C-141	64
C-130	200
C-X	TBD

Mission 2a: Long-Range with No Air Refueling



C-5, C-141, C-X:MOB-DOB/C-X:MOB-SAAF, DOB-SAAF

265,000 Tons in 25 days

Daily Missions Available:

C-5	24
C-141	61
C-130	200
C-X	TBD

Mission 3: Theater Deployment

500 nm

FOB → SAAF

C-130, C-X

42,500 Tons in 4 days

Daily Missions Available:

C-130	200
C-X	TBD

SOURCE Thomas D. Pilsch, "The C-X Requirement: Perspective on Airlift," <u>Airlift Operations Review</u>, (January 1981): pp. 10-15.

Appendix D

C-X RFP AIRLIFT DEFINITIONS

This appendix contains airfield environment specifications identified in the C-X Request for Proposal. The physical limitations of main operating bases (MOBs), deployment operating bases (DOBs), forward operating bases (FOBs), and short, austere airfields (SAAFs) are depicted below.

1. MOBs - DOBS : Enroute bases are defined as follows:

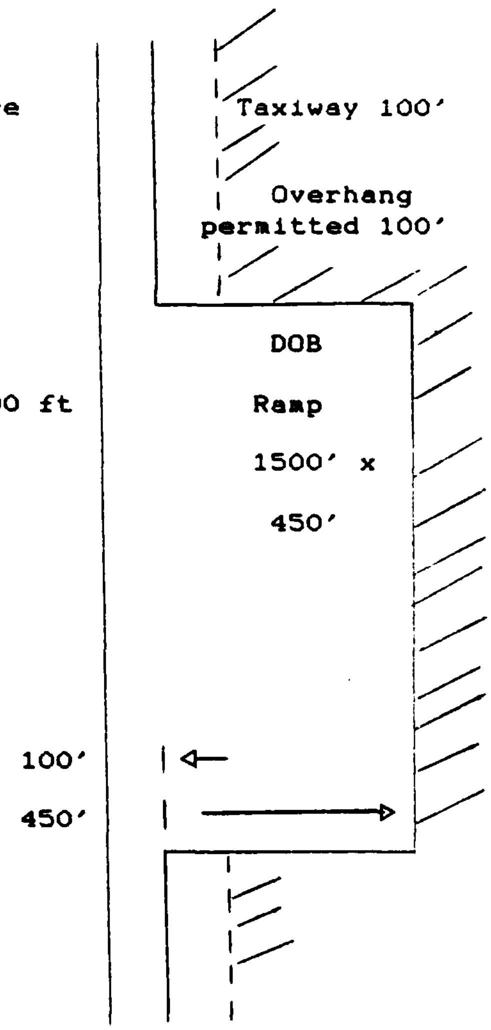
   Runway Length : 8500 ft

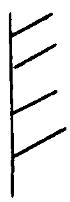
   Runway Width - 150 ft

   Runway Surface - LCG Class III

   C-X ramp space - 450 ft by 1500 ft

   Parallel taxiway - 100 ft



Obstruction 

2. FOBs are defined as follows:

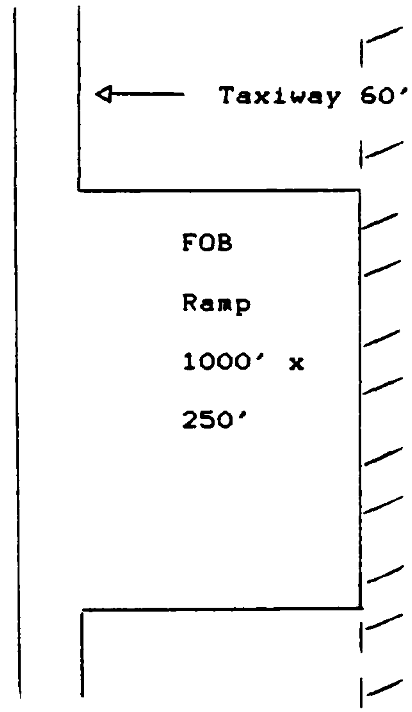
Runway Length - 6000 ft

Runway Width - 150 ft

Runway Surface - LCG Class III

C-X ramp space - 250 by 1000 ft

Taxiways - 60 ft wide



Obstruction 

3. SAAFs are all defined as follows:

NOTE: Obstacle clearance. For runways, no obstacle will extend above a line starting at the runway edge and extending 40 feet at an upward gradient of 5% then changing to a safety zone extending indefinitely at a gradient of 14.2%. For taxiways, no obstacle will extend above a line starting at the taxiway edge and extending for 70 feet at a gradient of 10% then changing to a safety zone extending indefinitely at a gradient of 14.2% No part of any C-X aircraft shall overhang the above areas with less than 5 feet vertical or 25 foot horizontal clearance with all landing gear on the runway/taxiway.

Type A

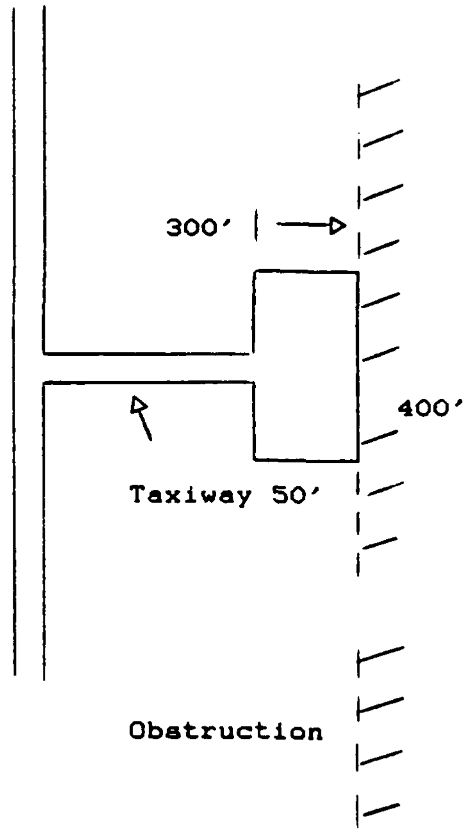
Runway Length - 4000 ft

Runway Width - 90 ft

Runway Surface - LCG Class IV

Total Ramp Space - 300 by 400 ft

Single Taxiway from runway center to ramp - 50 ft wide



Type B

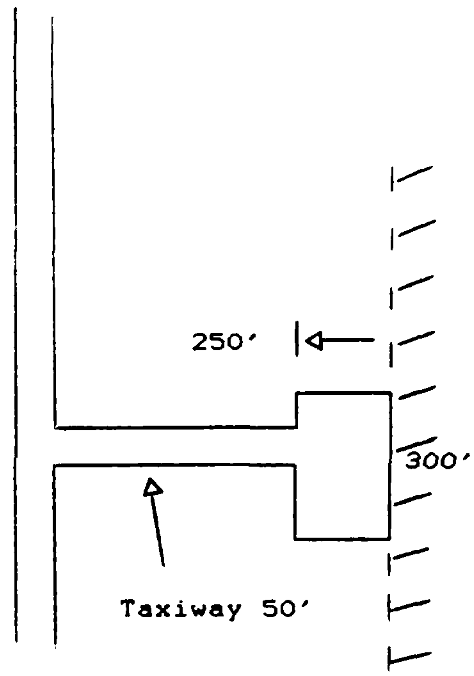
Runway Length - 3000 ft

Runway Width : 90 ft

Runway Surface - LCG Class IV

Total ramp space - 300 by 250 ft

Single taxiway from runway center
to ramp - 50 ft wide



SOURCE U.S. Air Force Systems Command, <u>C-X Request for Proposal (RFP) Volume I</u> (April 1980); Appendix 2, pp. 9-11.

Appendix E

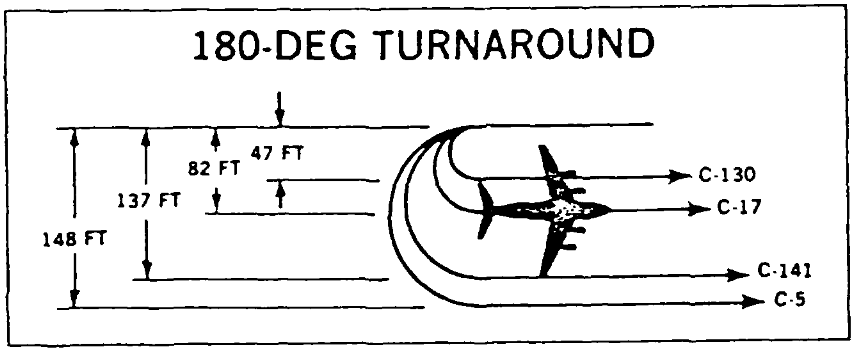
An analysis of the C-X Task Force Airfield survey results.

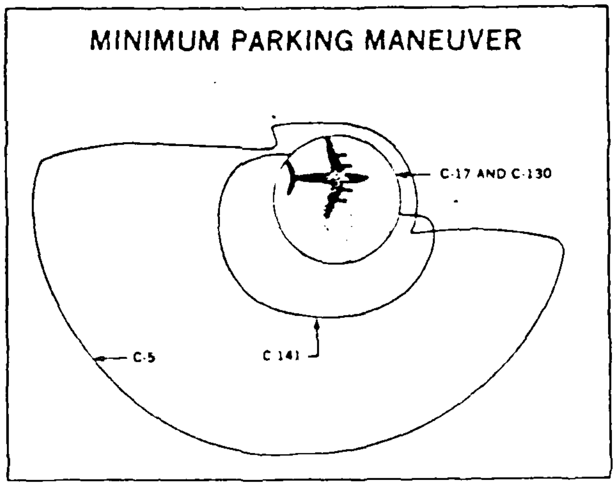
RUNWAYS LENGTH X WIDTH	AFRICA	CENTRAL EUROPE	SOUTH AMERICA	MIDDLE EAST	FREE WORLD LESS U.S.
≥5000 X ≥150	201	56	157	144	1576
≥5000 X ≥90	641	247	535	393	3488
≥4000 X ≥90	1059	294	1182	480	5640
≥3000 X ≥90	1902	436	2837	586	9887
≥2000 X ≥90	2702	710	4855	640	15165

SOURCE Steven D. Acuff and Jeffrey L. Wise, <u>Introduction of the C-17 into the Military Airlift Command Airlift Force</u> (Research Report, Air Command and Staff College, March 1982): p. 74.

Appendix F

An airlift aircraft ground maneuverability comparison.



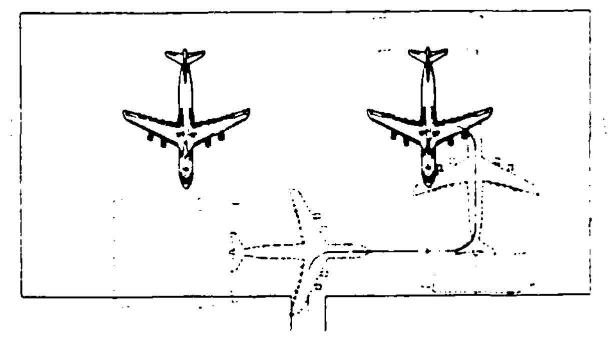


SOURCE Everett A. Chambers, "Airlift: Finding the Plane to Fit the Mission," Armed Forces Journal, (November 1982): p. 41.

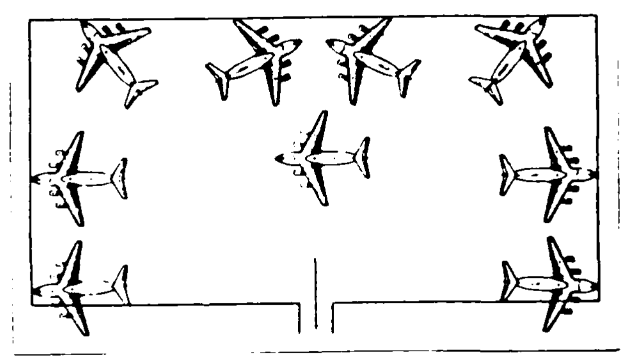
Appendix G

A comparison of C-5 and C-17 parking area requirements.

TWO C-5As
Ramp Are 500,000 ft Center Entry



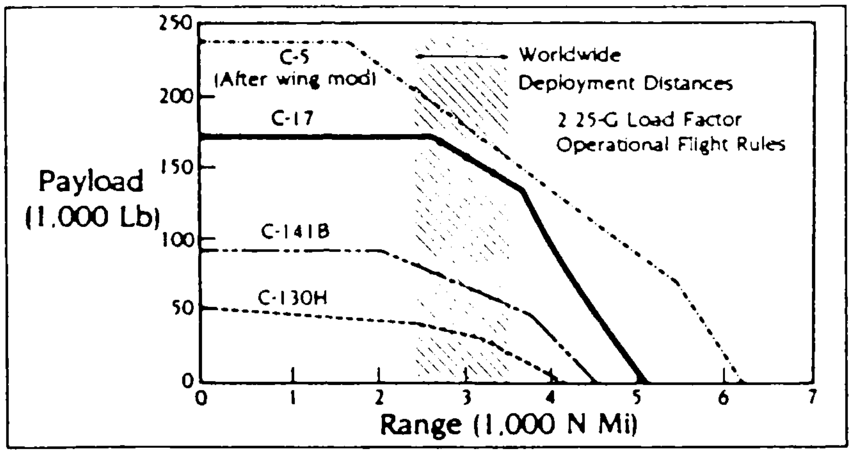
NINE C-17s
Ramp Area 500,000 ft Center Entry



SOURCE Everett A. Chambers, "Airlift: Finding the Plane to Fit the Mission," Armed Forces Journal, (November 1982): p. 44.

Appendix H

A comparison of C-5 and C-17 range and payload capability.



SOURCE McDonnell Douglas Corporation, "The New Direct-Delivery Airlifter," Airlift Operations Review, (January 1982): p. 13.

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